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PROCEEDINGS
OF THE
THIRTY-THIRD ANNUAL MEETING

Held at Atlantic City, New Jersey
June 23-27, 1930

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PART I. COMMITTEE REPORTS
NEW AND REVISED TENTATIVE STANDARDS
TENTATIVE REVISIONS OF STANDARDS

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Submitted or Revised, 1930

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American Society for Testing Materials

ORGANIZED IN 1898
INCORPORATED IN 1902

PROCEEDINGS, PART I

The Society is not responsible, as a body, for the statements and opinions advanced in this publication.

SUMMARY OF THE PROCEEDINGS OF THE THIRTY-THIRD ANNUAL MEETING

ATLANTIC CITY, N. J., JUNE 23–27, 1930

THE THIRTY-THIRD ANNUAL MEETING OF THE AMERICAN SOCIETY FOR TESTING MATERIALS was held at Chalfonte-Haddon Hall, Atlantic City, N. J., June 23–27, 1930. The following is an analysis of the registered attendance at the meeting: Members in attendance or represented, 954; guests, 138; total, 1092; ladies, 269. The corresponding statistics for the Thirty-second Annual Meeting are: Members in attendance or represented, 819; guests, 115; total, 934; ladies, 269.

FIRST SESSION—TUESDAY, JUNE 24, 2 P. M.

Reports of Administrative Committees; Testing and Testing Apparatus

President T. D. Lynch in the chair.

The President in opening the annual meeting directed attention to the many accomplishments and activities of the Society's committees that were of unusual interest. He stated that the life of the Society was largely manifested in the work of the standing committees. This was reflected in the very complete program of the meeting, replete with many interesting and valuable reports. The program also contained many interesting papers representing contributions from the membership of the Society.

The minutes of the Thirty-second Annual Meeting were approved as printed in the 1929 Proceedings.

President Lynch appointed a Committee of Tellers consisting of H. M. Boylston, chairman, H. A. Schwartz and G. L. Norris to canvass the vote on the election of officers, the report of the tellers to be received at the Seventh Session.

The report of Committee E-6 on Papers and Publications was presented by the chairman, C. L. Warwick. On motion, the report of the committee was adopted.

The report of Committee E-9 on Correlation of Research was presented by the chairman, H. F. Moore. On motion, the report of the committee was adopted.

The report of Committee E-10 on Standards reporting on the organization of the committee and the work it plans to pursue was presented by the chairman, T. R. Lawson. On motion, the report of the committee was adopted.

A paper entitled "Specimens for Torsion Tests of Metals" by R. L. Templin and R. L. Moore was presented by Mr. Templin, and discussed.

A paper entitled "Elastic Behavior of Spring Materials" by M. F. Sayre was presented by the author.

A paper entitled "Hardness by Mutual Indentation" by Irving H. Cowdrey, in the absence of the author was presented by title.

A paper entitled "A Magnetic Strain Gage" by J. Paul Shamberger, in the absence of the author, was presented by Charles Jablow and discussed.

The report of Committee E-1 on Methods of Testing was presented by the chairman, W. H. Fulweiler. The proposed advancement to standard of the definitions of stress, strain, stress-strain diagram, tensile strength, compressive strength and modulus of elasticity appearing in the Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 25 T) was approved for reference to letter ballot of the Society for adoption. Announcement was made that the revisions proposed in the Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 28 T), in the Standard Method of Test for Distillation of Creosote Oil (D 246 – 28), in the Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 – 27) and in the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 28) had all been approved by Committee E-1 and their approval by the Society would be asked for by the several standing committees having jurisdiction over these standards.

In presenting the report Mr. Fulweiler called on H. F. Moore to present the report of the Technical Committee on Mechanical Testing, on J. M. Lessells to present the Résumé of the Present Status of the Impact Test and on L. T. Work to describe the work of the Technical Committee on Size and Shape. On motion, the report of the committee was adopted.

The report of Committee E-8 on Nomenclature and Definitions was presented by the chairman, Cloyd M. Chapman. In presenting the report Mr. Chapman called on the secretary of the committee, R. E. Hess, to present the detailed recommendations of the committee and the actions of Committee E-8 on recommendations by standing committees for adoption as standard of definitions of terms. These included definitions relating to methods of testing, to wrought iron specifications, to heat treatment operations, to coal and coke, to timber, to textile materials, and to gypsum. The committee's recommended form of note to definitions was approved. On motion, the report of the committee was adopted.

The meeting then adjourned till 8 p. m.

SECOND SESSION—TUESDAY, JUNE 24, 8 P. M.

On Wrought Iron, Cast Iron, Magnetics, Metallography, and Metals at High Temperatures

(Held Simultaneously with Third Session)

Mr. T. R. Lawson in the chair.

The report of Committee A-2 on Wrought Iron was presented by the chairman, H. W. Faus. The revisions proposed for immediate adoption in the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27), for Welded Wrought-Iron Pipe (A 72 – 27), for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27), for Hollow Rolled Staybolt Iron (A 86 – 27), for Refined Wrought-Iron Bars (A 41 – 18), for Wrought-Iron Plates (A 42 – 18), for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 24), and Definitions of Terms Relating to Wrought-Iron Specifications (A 81–27) were unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. In offering the revisions of Definitions A 81 – 27, the chairman presented a number of editorial changes that the committee planned to make in several definitions on the recommendation of Committee E-8 on Nomenclature and Definitions.

The proposed revision and advancement to standard of the Tentative Specifications for Iron and Steel Chain (A 56 – 28 T) was approved for reference to letter ballot of the Society for adoption as standard, to supersede the present Standard Specifications for Iron and Steel Chain (A 56 – 24).

The proposed adoption of the tentative revisions of the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded

Iron Boiler Tubes (A 83 – 27), for Welded Wrought-Iron Pipe (A 72 – 27), for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27), and for Hollow Rolled Staybolt Iron (A 86 – 27) were approved for reference to letter ballot of the Society for advancement to standard.

In presenting the report Mr. Faus called on J. H. Higgins to present the paper entitled "Investigation of the Effect of Phosphorus on Wrought Iron" appended to the report. On motion, the report of the committee was adopted.

The report of Committee A-3 on Cast Iron was presented by the chairman, Hyman Bornstein. In presenting the report Mr. Bornstein called on A. L. Boegehold to present the paper entitled "Effect of Section Size on Physical Properties of Cast Iron," appended to the report. This paper was then discussed. The chairman then called on J. A. Capp to present the paper entitled "Comparison of the Physical Properties of Different Sections of Cast Iron and of the Standard Arbitration Test Bar" by M. V. Healey, appended to the report.

The proposed revision of the Standard Specifications for High-Test Gray-Iron Castings (A 88 – 29) was approved for publication as tentative.

The proposed revision of the Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 29 T) was accepted, the specifications as revised being continued as tentative.

The committee recommended that the Tentative Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 – 29 T) be advanced to standard without revision. After discussion the recommendation was on motion approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

The report of Committee A-7 on Malleable Castings was presented by the chairman, W. P. Putnam. The proposed immediate revision of the Standard Specifications for Malleable Castings (A 47 – 27) was approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. On motion, the report of the committee was adopted.

The report of Committee A-6 on Magnetic Properties was presented by the chairman, Thomas Spooner. The proposed revision of the Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 29 T) was accepted, the definitions as revised being continued as tentative.

The proposed revision of the Standard Methods of Test for

Magnetic Properties of Iron and Steel (A 34 – 28) was accepted for publication as tentative. On motion, the report of the committee was adopted.

A paper entitled "The Unbalanced Alternating Current Bridge for Magnetic Analysis" by W. B. Kouwenhoven and A. C. Seletzky was presented by Mr. Seletzky and discussed.

The report of the Joint Research Committee of the A.S.M.E. and A.S.T.M. on Effect of Temperature on the Properties of Metals was presented from manuscript by the chairman, H. J. French. In presenting the report Mr. French called on H. C. Cross to present the "Second Report on Comparative High-Temperature Tension Tests of Metals at Different Laboratories." Another paper appended to the report entitled "Some Long-Time Tension Tests of Steels at Elevated Temperatures" by J. J. Kanter and L. W. Spring was presented by Mr. Kanter. On motion, the report of the committee was adopted.

A paper entitled "The Effect of Temperature upon the Torsional Modulus of Spring Materials" by F. P. Zimmerli, W. P. Wood and G. D. Wilson was presented by Mr. Wood.

The report of Committee E-4 on Metallography was presented by the chairman, H. C. Boynton. The committee withdrew the proposed revision of the definition of the term "grain" appearing in the report as preprinted. The proposed revision of the Tentative Recommended Practice for the Thermal Analysis of Steel (E 14 – 25 T) was accepted, the recommended practice as revised being continued as tentative. The proposed revision of the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (E 2 – 27) was unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. On motion, the report of the committee was adopted.

The meeting then adjourned till the following morning.

THIRD SESSION—TUESDAY, JUNE 24, 8 P. M.

On Rubber, Textiles, Coal

(Held Simultaneously with Second Session)

Past-President J. H. Gibboney in the chair.

A paper entitled "A Study of Performance Characteristics of a 4-in. 4-ply Rubber Transmission Belt" was presented from manuscript by the author, J. E. Skane, and discussed.

The report of Committee D-11 on Rubber Products was, in the absence of the chairman, W. B. Wiegand, presented by the secretary, Arthur W. Carpenter. On motion, the report of the committee was adopted.

A paper entitled "Stretch in Rubber Transmission Belting" by C. W. Staacke was presented by the author and discussed.

A paper entitled "Service Tests on Rubber Belts" by E. G. Kimmich was presented by the author and discussed.

A paper entitled "Laboratory Flexing Tests as an Aid in Investigating the Pneumatic Tire Carcass" by H. A. Depew and H. C. Jones was presented by Mr. Depew and discussed.

The report of Committee D-13 on Textile Materials was presented by the chairman, W. H. Whitcomb. The proposed revisions of the Standard General Methods of Testing Woven Textile Fabrics (D 39 – 27), and of the Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 29) were accepted for publication as tentative. The proposed revisions of the Standard Specifications for Textile Testing Machines (D 76 – 27) involved a patented device. On motion, the proposed revisions were accepted for publication as tentative subject to the approval of the Executive Committee of the Society after reviewing the situation in respect to patent features.[1] The proposed immediate revision of the Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (D 122 – 27) and for Tolerances and Test Methods for Cord Tire Fabrics (D 179 – 27) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revision of the Tentative Specifications for Chafer Tire Fabrics (D 316 – 29 T) and the Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 – 29 T) was approved, the specifications and methods as revised being continued as tentative. The proposed advancement to standard of the definitions of the terms loop knot, regain, and gage, as revised, were approved for submission to letter ballot of the Society for adoption.

The withdrawal of the Tentative Methods of Testing Cotton Fibers (D 152 – 22 T) was approved. On motion, the report of the committee was adopted.

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[1] The Executive Committee has not approved the proposed revisions and accordingly they will not be published as tentative.

A paper entitled "Thermal Transmission of Fabrics" by Ephraim Freedman was presented by the author and discussed.

The report of Committee D-5 on Coal and Coke was presented by the chairman, A. C. Fieldner. The advancement to standard of the Tentative Methods of Test for Fineness of Powdered Coal (D 197 – 26 T) and for Sieve Analysis of Crushed Bituminous Coal (D 311 – 29 T) was approved for reference to letter ballot of the Society for adoption.

The report as preprinted had recommended that the definitions of the terms coke, beehive coke, by-product coke, coke breeze and dry coke appearing in the Tentative Definitions of Terms Relating to Coal and Coke (D 121 – 27 T) be advanced to standard with the terms coke, by-product coke, and dry coke revised as indicated in the report. As a result of suggestions from Committee E-8 on Nomenclature and Definitions, Committee D-5 recommended that the definition of the term coke be continued as tentative and that the other definitions be adopted. This recommendation was accepted and the definitions approved for reference to letter ballot of the Society for adoption as standard.

The advancement to standard of the tentative revisions of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 29) was approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

The report of the Sectional Committee on Classification of Coals was presented by the chairman, A. C. Fieldner. On motion, the report of the committee was accepted for publication.

The meeting then adjourned till the following morning.

Fourth Session—Wednesday, June 25, 9.30 a. m.

On Steel

(Held Simultaneously with Fifth Session)

Past-President A. A. Stevenson in the chair.

The report of Committee A-1 on Steel was presented by the chairman, J. B. Young. The proposed Tentative Specifications for Austenitic Manganese-Steel Castings and Specifications for Open-Hearth Iron Plates of Flange Quality were accepted for publication as tentative.

The revisions proposed for immediate adoption in the Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 –

27), for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 27), for Steel Plates of Structural Quality for Forge Welding (A 78 – 27), for Steel Plates of Flange Quality for Forge Welding (A 89 – 27) and for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27) were unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed revisions of the Standards Specifications for Structural Steel for Ships (A 12 – 21) and for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 27) were accepted for publication as tentative.

The Tentative Specifications for Steel Tie Plates (A 67 – 26 T) were accepted and approved for reference to letter ballot of the Society for adoption. The Tentative Specifications for Iron and Steel Chain (A 56 – 28 T) as revised were approved for reference to letter ballot of the Society for adoption, to supersede the present Standard Specifications for Iron and Steel Chain (A 56 – 24). The Tentative Methods of Sampling Rolled and Forged Steel Products for Check Analysis (A 33 – 28 T) were approved for reference to letter ballot of the Society for adoption.

The advancement to standard of the tentative revisions of the following standard specifications was approved for reference to letter ballot of the Society for adoption:

For Open-Hearth Carbon-Steel Rails (A 1 – 27);
For Billet-Steel Concrete Reinforcement Bars (A 15 – 14);
For Carbon-Steel and Alloy-Steel Forgings (A 18 – 28);
For Welded and Seamless Steel Pipe (A 53 – 27);
For Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27).

On motion, the report of the committee was adopted.

A paper entitled "The New Manganese Alloy Steels" by E. E. Thum was presented by the author and discussed.

A paper entitled "The Relative Merits of Some Different Alloy Steels with Respect to Certain Mechanical Properties" by Bradley Stoughton and Wilber E. Harvey was presented by Mr. Stoughton and discussed.

The report of Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys was presented by the chairman, Jerome Strauss. In presenting the report mention was made of the compilation of manufacturers' data on corrosion-resistant alloys that was being prepared for publication with the report in the *Proceedings*. On motion, the report of the committee was adopted.

A paper entitled "Some Effects of Nickel Content in Austenitic Iron-Chromium-Nickel Alloys" by N. B. Pilling was presented by the author and discussed.

A paper entitled "Investigation of Cold-Drawn Bridge Wire" by L. S. Moisseiff was presented by the author from manuscript and discussed.

The report of the Research Committee on Yield Point of Structural Steel was presented from manuscript by the chairman, M. O. Withey. On motion, the report of the committee was accepted for publication.

The report of Committee A-4 on Heat Treatment of Iron and Steel was presented by the chairman, H. M. Boylston. The advancement to standard of the Tentative Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys) (A 119 - 28 T), revised as recommended by the committee, was approved for reference to letter ballot of the Society for adoption as standard. On motion, the report of the committee was adopted.

The report of the Sectional Committee on Standardization of Dimensions and Material of Wrought-Iron and Wrought-Steel Pipe and Tubing was presented by the chairman, H. H. Morgan. On motion, the report of the committee was accepted for publication.

The meeting then adjourned till 4 P. M.

FIFTH SESSION—WEDNESDAY, JUNE 25, 9.30 A. M.

On Petroleum Products, Road and Waterproofing Materials, Electrical Insulating Materials

(Held Simultaneously with Fourth Session)

Vice-President K. G. Mackenzie in the chair.

The report of Committee D-2 on Petroleum Products and Lubricants was presented by the chairman, F. A. Hull. The proposed Tentative Method of Test for Determination of Vapor Pressure of Natural Gasoline (Reid Method) and the Tentative Method of Test for Dilution of Crankcase Oil were accepted for publication as tentative. The revisions recommended for immediate adoption in the Standard Methods of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 - 27), for Cloud and Pour Points of Petroleum Products (D 97 - 28), for Burning Quality of Kerosine Oils (D 187 - 27), for Burning Quality of Mineral Seal Oils (D 239 - 27), and for Burning Quality of Long-Time Burning

Oil for Railway Use (D 219 – 27) were approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. As preprinted the report had recommended that three standard methods, namely, the Standard Methods of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 28), for Distillation of Natural Gas Gasoline (D 216 – 27) and for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 – 28) be revised immediately and continued as standard. This committee recommended changes in the revisions as preprinted of these three standards as follows:

Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 28):

Section 4.—Change the first three lines of the dimensions for the A.S.T.M. Cone-Shaped Tube from the following form as preprinted:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0.0 to 0.25 ml.	0.05 ml.	0.02 ml.	....
0.25 to 0.50 ml.	0.05 ml.	0.03 ml.	½ ml.
0.50 to 3 ml.	0.1 ml.	0.05 ml.	1, 2, 3 ml.

to read as follows:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 0.1 ml.	0.05 ml.	0.02 ml.	....
0.1 to 0.3 ml.	0.05 ml.	0.03 ml.	....
0.3 to 0.5 ml.	0.05 ml.	0.05 ml.	½ ml.
0.5 to 1.0 ml.	0.1 ml.	0.05 ml.	1 ml.
1 to 3 ml.	0.1 ml.	0.1 ml.	2, 3 ml.

Standard Method of Test for Distillation of Natural Gas Gasoline (D 216 – 27):

Section 9 (f).—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The graduate shall be immersed [at least] up to the [100-cc. mark] *level of the outlet of the condenser tube* in a transparent bath maintained between the temperatures of 32 and 34° F. (0 and 1.1° C.).

Section 10.—Omit the recommended revision in the second and third paragraphs of this section.

Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 – 28):

Section 2.—Change the revised Paragraphs (*a*), (*b*) and (*c*) from the form recommended in the report as preprinted: namely,

(*a*) Porcelain crucible, wide form, glazed throughout, or a silica crucible; 23 to 26 ml. capacity, 46 mm. (1.81 in.) in approximate rim diameter.

(*b*) Skidmore iron crucible flanged and ringed, 65 to 82-ml. approximate capacity, 53 to 57 mm. (2.07 to 2.20 in.) inside and 60 to 67 mm. (2.36 to 2.64 in.) outside diameter of flange, 37 to 39 mm. (about 1.46 to 1.54 in.) in height supplied with a cover without delivery tubes and having the vertical opening closed. The horizontal opening of about 6.5 mm. (0.26 in.) shall be kept clean. The outside diameter of the flat bottom shall be about 31 mm. (1.22 in.) from which the sides shall curve outwardly to a distance of about 20 mm. (0.79 in.) in perpendicular height, above which they are straight to the flange.

(*c*) Spun sheet-iron crucible, with cover; 80 mm. (3.15 in.) in outside diameter at the top, 58 to 60 mm. (about 2.3 in.) in height, and approximately 0.8 mm. (0.03 in.) in thickness. Place at the bottom of this crucible, and level before each test, a layer of about 25 ml. of dry sand, or enough to bring the Skidmore crucible, with cover on, nearly to the top of the sheet-iron crucible.

to read as follows:

(*a*) Porcelain crucible, wide form, glazed throughout, or a silica crucible; 29 to 31-ml. capacity, 46 to 49 mm. (1.81 to 1.93 in.) in rim diameter.

(*b*) Skidmore iron crucible flanged and ringed, 65 to 82-ml. capacity, 53 to 57 mm. (2.07 to 2.20 in.) inside and 60 to 67 mm. (2.36 to 2.64 in.) outside diameter of flange, 37 to 39 mm. (1.46 to 1.54 in.) in height supplied with a cover without delivery tubes and having the vertical opening closed. The horizontal opening of about 6.5 mm. (0.26 in.) shall be kept clean. The outside diameter of the flat bottom shall be 30 to 32 mm. (1.18 to 1.26 in.).

(*c*) Spun sheet-iron crucible, with cover; 78 to 82 mm. (3.07 to 3.23 in.) in outside diameter at the top, 58 to 60 mm. (about 2.3 in.) in height, and approximately 0.8 mm. (0.03 in.) in thickness. Place at the bottom of this crucible, and level before each test, a layer of about 25 ml. of dry sand, or enough to bring the Skidmore crucible, with cover on, nearly to the top of the sheet-iron crucible.

Section 3.—At the end of the third paragraph add the following sentence:

The period of burning the vapors shall not be less than 12 nor more than 14 minutes.

The methods as revised were accepted and approved for reference to letter ballot of the Society for adoption as standard subject to a subsequent favorable letter ballot of Committee D-2.[1]

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[1] The subsequent letter ballot on these recommendations resulted as follows: Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 28), 54 affirmative, 1 negative, with 3 members not voting; Standard Method of Test for Distillation of Natural Gas Gasoline (D 216 – 27), 55 affirmative, none negative, with 3 members not voting; Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 – 28), 56 affirmative, 1 negative, with 1 member not voting.

The advancement to standard of the tentative revisions of the Standard Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 – 26), for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 – 27) and for Water in Petroleum Products and Other Bituminous Materials (D 95 – 28) were approved for reference to letter ballot of the Society for adoption.

The proposed revisions of the Tentative Method of Test for Sulfur in Motor Fuels, Naphthas and Illuminating Oils (Lamp Method) (D 90 – 29 T), Methods of Sampling Petroleum and Petroleum Products (D 270 – 27 T) and Test for Distillation of Crude Petroleum (D 285 – 29 T) were accepted, the methods as revised being continued as tentative.

In the report as preprinted the committee had also recommended revisions in the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 28 T) and Test for Precipitation Number of Lubricating Oils (D 91 – 29 T). The committee recommended changes in the revisions of these two tentative methods as preprinted. These changes are as follows:

Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 28 T):

Section 3.—Change the sentence recommended to be added to this section to read as follows by the omission of the words in brackets:

> The gravity scale shall be printed in black ink. [in order to avoid any possibility of confusion with the red temperature scale used with the paper-scale type of thermometer contained in thermo-hydrometers (see Section 4 (*b*)).]

Section 4.—Omit the recommended revision in Paragraph (*a*), as preprinted, in the sections on Range and Subdivision and on Graduations.

Change the second sentence of Paragraph (*b*) from the following form as preprinted:

> The paper temperature scale shall be graduated in 2° F. divisions accurate to ±1° F. (Note) and shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale (see Section 3).

to read as follows:

> The paper temperature scale shall be graduated in 2° F. divisions accurate to ±1° F. (Note) and, when located in the stem of the hydrometer, shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale.

Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 – 29 T):

Section 4.—Change the first three lines of the dimensions for the A.S.T.M. Cone-Shaped Tube from the following form as preprinted:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0.0 to 0.25 ml.	0.05 ml.	0.02 ml.	....
0.25 to 0.50 ml.	0.05 ml.	0.03 ml.	½ ml.
0.5 to 3 ml.	0.1 ml.	0.05 ml.	1, 2, 3 ml.

to read as follows:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 0.1 ml.	0.05 ml.	0.02 ml.	....
0.1 to 0.3 ml.	0.05 ml.	0.03 ml.	....
0.3 to 0.5 ml.	0.05 ml.	0.05 ml.	½ ml.
0.5 to 1.0 ml.	0.1 ml.	0.05 ml.	1 ml.
1 to 3 ml.	0.1 ml.	0.1 ml.	2, 3 ml.

With these revisions in the original recommendation the changes in the methods were approved, the methods as revised being continued as tentative, subject to a subsequent favorable letter ballot of Committee D-2.[1]

The advancement to standard of the Tentative Methods of Test for Melting Point of Petroleum (D 127 – 28 T), for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline (D 130 – 27 T) and for the Determination of Autogenous Ignition Temperatures (D 286 – 28 T) was accepted for reference to letter ballot of the Society for adoption.

The withdrawal of the tentative revision proposed in 1928 of the Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 – 28) was approved.

On motion, the report of the committee was adopted.

A paper entitled "Motor Performance as Determined by Fuel Volatility" by George Granger Brown was presented by the author and discussed.

The report of Committee D-9 on Electrical Insulating Materials, in the absence of the chairman, H. S. Vassar, was presented by the vice-chairman, Dean Harvey. The proposed Tentative Method of Test for Comparing the Thermal Conductivity of Solid Electrical Insulating Materials was accepted for publication as tentative.

The tentative revision of the Standard Methods of Testing Molded Insulating Materials (D 48 – 29) was approved for reference to letter ballot of the Society for adoption. An additional revision of these standard methods was also approved for reference to letter ballot of the Society for immediate adoption, this recommendation requiring a nine-tenths vote.

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[1] The subsequent letter ballot on these recommendations resulted as follows: Tentative Method of Test for Gravity of Petroleum Products by Means of the Hydrometer (D 287 – 28 T), 57 affirmative, none negative, with 1 member not voting; and the Test for Precipitation Number of Lubricating Oils (D 91 – 29 T), 54 affirmative, 1 negative, with 3 members not voting.

The proposed revisions of the following tentative methods were accepted, the methods as revised being continued as tentative:

Testing Insulating Varnishes (D 115 - 29 T);
Testing Sheet and Tape Insulating Materials for Dielectric Strength (D 149 - 27 T);
Testing Untreated Insulating Paper (D 202 - 29 T);
Testing Laminated Sheet Insulating Materials (D 229 - 28 T).

The advancement to standard of the Tentative Methods of Testing Electrical Porcelain (D 116 - 29 T) was approved for reference to letter ballot of the Society for adoption.

On motion, the report of the committee was adopted.

A paper entitled "The Testing of Condenser Paper" by F. L. Roman, in the absence of the author, was presented by W. A. Straw.

The report of Committee D-4 on Road and Paving Materials was presented by the chairman, R. W. Crum. The proposed revision of the Tentative Specifications for Calcium Chloride for Dust Prevention (D 98 - 22 T) was accepted, the specifications as revised being continued as tentative.

The revision proposed for immediate adoption in the Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 - 27) was unanimously approved for reference to letter ballot of the Society for adoption as standard, this recommendation requiring a nine-tenths vote.

The proposed advancement to standard of the following tentative specifications and method, with revisions proposed in those indicated, was approved for reference to letter ballot of the Society for adoption:

Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 28 T), as revised.
Tentative Specifications for:
  High-Carbon Tar for Surface Treatment, Cold Application (D 104 - 27 T), as revised;
  Low-Carbon Tar for Surface Treatment, Cold Application (D 105 - 27 T), as revised;
  High-Carbon Tar for Surface Treatment, Hot Application (D 108 - 27 T);
  Low-Carbon Tar for Surface Treatment, Hot Application (D 109 - 27 T);

High-Carbon Tar Cement (D 110 – 27 T);
Low-Carbon Tar Cement (D 111 – 27 T);
Coal-Tar Pitch for Stone Block Filler (D 112 – 27 T);
Gravel for Bituminous Concrete Base (D 309 – 29 T).

On motion, the report of the committee was adopted.

The report of Committee D-8 on Bituminous Waterproofing and Roofing Materials was presented by the chairman, S. T. Wagner. The Tentative Specifications for Acid-Resisting Asphalt Mastic (D 223 – 25 T) were approved for reference to letter ballot of the Society for advancement to standard.

The proposed withdrawal of the Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules (D 228 – 27) as a standard method of the Society and the publication of these methods as a tentative standard was approved.

On motion, the report of the committee was adopted.

The report of Committee D-15 on Thermometers was presented by the chairman, W. H. Fulweiler. The proposed revision of the Tentative Specifications for Thermometers for Engler Viscosimeters (D 300 – 28 T) was accepted, the specifications as revised being continued as tentative. On motion, the report of the committee was adopted.

The meeting then adjourned till 4 P. M.

SIXTH SESSION—WEDNESDAY, JUNE 25, 4 P. M.

Edgar Marburg Lecture and Award of Charles B. Dudley Medal

President T. D. Lynch in the chair.

The President, in opening the session explained briefly the institution of the Edgar Marburg Lectures, and the double significance attached to them, namely, that they were established for the purpose of annually commemorating the name of the first Secretary-Treasurer of the Society, one who contributed so largely to its early character and development, and to bring to the Society men of especial distinction in various branches of the engineering profession to the end that the members might learn through the lecture of the latest developments in the sciences of materials in which the Society is interested.

The President then introduced as the fifth Edgar Marburg Lecturer, Dr. C. E. Kenneth Mees, Director of Research and Development of the Eastman Kodak Co., who chose as the subject of his lecture, "Color and Its Measurement." Doctor Mees presented a very interesting description of the theory of color analysis and synthesis, with an experimental screen demonstration by means of prisms and special apparatus. He discussed the physical nature of color, involving a consideration of the nature of light, and the methods which can be used for measuring it and for its standardization. He pointed out that a knowledge of light is attained through the eye. The sensation produced upon the eye by an object has three attributes: the brilliance, dependent upon the intensity of the light; the hue and the saturation. All three of these components are capable of change independently. He stated that one great problem in colorimetry as applied to industry is the measurement of very faint colors and that the criterion of color in colorimetry is the eye and that no colorimeter is more sensitive than the eye to small differences in color. Doctor Mees predicted that the measurement of color both analytically by means of the spectrophotometer and synthetically by means of colorimeters will increase and form an important part of the work of laboratories devoted to the testing of materials.

President Lynch, in thanking Doctor Mees for the excellent address, presented to him on behalf of the Society the Edgar Marburg Lecture Certificate.

President Lynch then recognized H. S. Vassar, chairman of the Committee on Award of the Charles B. Dudley Medal. Mr. Vassar in presenting the recipients of the award made the following remarks:

> The Committee on Award of the Charles B. Dudley Medal has been charged with the task of selecting, from among the papers presented at the last annual meeting a "paper of outstanding merit constituting an original contribution on research in materials," to whose author or authors the fourth Charles B. Dudley Medal will be awarded. At the beginning of its work the committee was confronted with the usual difficulty brought about by the wealth of creditable papers eligible for the award. Many of these papers showed the results of careful research and were presented in a form making them of enduring value to the work of the Society. The choice of your committee this year again falls in the field of metals. In reviewing and evaluating the eligible papers, the committee has been influenced by the following considerations: (1) Industrial significance or value to the work of the Society; (2) thoroughness in prosecution of the investigation; (3) form in which results have been presented.
>
> In these and other particulars, we consider the paper selected to be of outstanding merit. The winning paper entitled "Physical Properties and Methods of Test for Some Sheet Non-Ferrous Metals" has resulted in part from the continuation of an investigation reported to the Society in 1927. It deals with the development of more reliable methods of test for this class of materials, including the setting up of some commercial test limits.
>
> Mr. President, on behalf of the committee, I take pleasure in presenting the joint authors of this paper, Mr. J. R. Townsend, Mr. C. H. Davis and Mr. W. A. Straw.

President Lynch then made the fourth award of the Charles B. Dudley Medal to Messrs. J. R. Townsend, W. A. Straw and C. H. Davis, joint authors of the paper entitled "Physical Properties and Methods of Test for Some Sheet Non-Ferrous Metals."

Speaking for the authors Mr. Straw expressed appreciation of the honor, as follows:

> In behalf of the co-authors, Mr. Davis, Mr. Townsend and myself, I am glad to express our sincere appreciation to you and through you to the Society for the honor of recognition that these medals convey. We accept them with some gratification, but with due acknowledgment of the part others in our respective organizations have contributed. The work was begun in 1925 and a preliminary report was published in the *Proceedings* of this Society in 1927 by Messrs. H. N. Van Deusen, L. I. Shaw and C. H. Davis. Others contributing important work in the study were Messrs. W. H. Bassett, R. M. Tree, Alden Merrill, G. S. Mallett, of the American Brass Co.; W. S. Hayford, C. H. Greenall, of the Bell Telephone Laboratories; and G. R. Brown and M. D. Helfrick, of the Western Electric Co. In addition Messrs. N. E. Newton and W. H. Eastlake, of the Northern Electric Co., of Montreal, participated in the periodic conferences. The study was begun with a view to obtaining more complete information on the properties of the sheet non-ferrous metals than was available. The group cooperating for the purpose included the Bell Telephone Laboratories, representing the engineering and design phase, the Western Electric Co. as the consumer, and the American Brass Co. as the producer of the sheet metals. The group was limited in personnel to one representative of each interest, in order that the work might be expedited, but with the understanding that the results would be published for the use of the industry in general. Other phases of the problem investigated, either prior to or during the present study, by individuals associated in the study, were reported separately in papers presented last year and the year before. Messrs. Townsend and Greenall presented a paper on "Fatigue Studies of Non-Ferrous Sheet Metals," Messrs. Bassett and Davis presented a paper on "Physical Characteristics of Commercial Copper-Zinc Alloys," Messrs. Davis and Munson presented a paper on the "Hardness Relationships and Physical Properties of Some Copper Alloys," and also will present at one of the current sessions of the Society a paper on "The Significance of Hardness Values for Some Copper-Zinc Alloys." Although carried on independently of the Society, we hope that the results of the work will be of sufficient merit and interest to be useful in the Society's standards and to encourage further studies along similar lines on these or other materials.

The meeting then adjourned till 8.15 p. m.

SEVENTH SESSION—WEDNESDAY, JUNE 25, 8.15 P. M.

Presidential Address and Report of Executive Committee

Past-President H. F. Moore in the chair.

The Secretary-Treasurer presented the annual report of the Executive Committee which discussed membership activities and activities of the numerous standing committees, publications, finances, publicity and administrative matters relating to committee activities, relations with other societies and international relations on various standardization projects. The following revision of the By-laws recommended by the Executive Committee was approved for reference to letter ballot of the Society for adoption:

Article VII, Dues.—Amend Section 1 to change the annual dues of Student Members from $3 to $1.50.

Coupled with this proposal is a resolution adopted by the Executive Committee, after consultation with the Committee on Papers and Publications, that under the lowered dues the student member shall receive a copy of the "Selected A.S.T.M. Standards for Students" in place of the complete Book of A.S.T.M. Standards as at present. Each student member will be supplied with the List of Standards and will be extended the privilege of obtaining copies of either part of the Book of A.S.T.M. Standards at the price (at present $2) at which members obtain the second part of that volume in addition to the part to which their dues entitle them, also to obtain copies of separate standards at practically cost price. Other privileges at present offered to student members will be continued, namely, to receive the Year Book and Bulletin, preprints of all reports and papers upon request, and the opportunity of securing copies of the annual *Proceedings* and other publications at the special prices to members.

On motion, the report of the Executive Committee was adopted.

The chairman then introduced President T. D. Lynch, who delivered the Annual Presidential Address.

Mr. Lynch pointed out that with the advances in engineering sciences, there is an increasing tendency to require materials to meet new developments and economic conditions and consequently modern designers must know by experiment what materials to use and just what stresses and for what length of time such materials will endure. Since we have had given to us in nature certain elements which make up the material universe and since these represent potentialities, it becomes necessary to study and direct the processing of them if we are to change these natural materials and render them serviceable to man. Materials engineers are expected to know and are asked to advise on these new applications, whether they be along physical, electrical, chemical or magnetic lines. President Lynch stated that the American spirit of accepting and using new information as it is made available prepares the way for greater developments and standards of the highest order, and that the Society conceives as one of its purposes the development of such standards when once the necessary information is available.

The chairman then presented G. H. Clamer, who made a short announcement concerning the Benjamin Franklin Memorial and Franklin Institute Museum to be erected in Philadelphia, Pa., as a memorial and tribute to Benjamin Franklin. He stated that the Society is directly interested in this memorial because of its interest in engineering materials, testing apparatus and procedures, exhibits of which will be shown in the museum.

The chairman stated that in view of the Society's interest in the Benjamin Franklin Memorial, the Executive Committee proposed to address a communication to the members of the Society to afford them an opportunity to participate in the fund for this Museum.

The chairman then recognized H. M. Boylston, chairman of the Committee of Tellers, who reported the results of the letter ballot on election of officers. Of the 1098 legal ballots cast, the results were as follows:

For President, to serve for one year: K. G. Mackenzie, 1096 votes.

For Vice-President, to serve for two years: Cloyd M. Chapman, 1094 votes.

For Members of Executive Committee, to serve for two years:

F. H. Jackson, 1095 votes.
Zay Jeffries, 1091 votes.
H. H. Quimby, 1090 votes.
G. A. Reinhardt, 1091 votes.
H. N. Van Deusen, 1092 votes.

In accordance with the ballot the chair declared the officers listed above elected.

The chairman then introduced the newly elected members of the Executive Committee.

At the request of the chairman, Past-President G. W. Thompson escorted the Vice-President-elect, Cloyd M. Chapman, to the chair. Mr. Chapman thanked the members for the honor bestowed upon him and stated that he realized the office was one of responsibility and that he would do his best to fulfill the requirements.

The chairman then requested Past-President A. A. Stevenson to escort the President-elect, K. G. Mackenzie, to the chair. Mr. Mackenzie expressed deep appreciation of the honor of his election to the presidency and stated he realized the obligations entailed and that with the selection of such capable officers to assist him a successful year for the Society was assured. He pointed out that a Society is an association of individuals, either with a common aim or for a common purpose and that success can be achieved only if every member contributes. He asked the continued cooperation of the membership especially along the lines of increased membership, use and publicity of the Society's standards and in the activities of the standing committees.

The meeting then adjourned till the following morning and was followed by an informal dance and smoker.

EIGHTH SESSION—THURSDAY, JUNE 26, 9.30 A. M.

On Fatigue and Corrosion of Metals

(Held Simultaneously with Ninth Session)

Vice-President F. O. Clements in the chair.

The report of the Research Committee on Fatigue of Metals was presented from manuscript by the chairman, H. F. Moore. On motion, the report of the committee was accepted for publication.

A paper entitled "The Effect of Under-Stressing on Cast Iron and Open-Hearth Iron" by J. B. Kommers was presented by the author and discussed.

A paper entitled "Fatigue Tests of Fillet Welds" by R. E. Peterson and C. H. Jennings, in the absence of the authors, was presented by J. M. Lessells.

A paper entitled "Fatigue Studies of Telephone Cable Sheath Alloys" by J. R. Townsend and C. H. Greenall was presented by Mr. Townsend and discussed.

A paper entitled "A Note on Fatigue Tests of Nitrided Steel" by N. L. Mochel was presented by the author.

A paper entitled "The Influence of Stress Range and Cycle Frequency on Corrosion," by D. J. McAdam, Jr., was presented from manuscript by the author and discussed.

The report of Committee A-5 on Corrosion of Iron and Steel, in the absence of the chairman, J. H. Gibboney, was presented by the vice-chairman, H. E. Smith. The revision proposed for immediate adoption in the Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 – 24) was accepted and unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

The proposed revision of the Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving (A 118 – 27 T) was accepted, the specifications as revised being continued as tentative.

The advancement to standard of the following tentative standards, with revisions in those as indicated, was accepted for reference to letter ballot of the Society for adoption:

Tentative Method of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 – 27 T), without revision.

Tentative Specifications for:

- Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire (A 111 – 27 T) as revised;
- Zinc-Coated (Galvanized) Iron or Steel Tie Wires (A 112 – 27 T) as revised;
- Zinc-Coated (Galvanized) Wire Fencing (A 116 – 27 T) as revised;
- Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving (A 117 – 27 T) as revised;
- Zinc-Coated (Galvanized) Barb Wire (A 121 – 28 T) as revised;
- Zinc-Coated (Galvanized) Steel Wire Strand (A 122 – 28 T).

On motion, the report of the committee was adopted.

The report of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys, in the absence of the chairman, T. S. Fuller, was presented by the vice-chairman, H. S. Rawdon. On motion, the report of the committee was adopted.

The report of Committee D-14 on Screen Wire Cloth was presented by the chairman, R. W. Woodward. In presenting the report Mr. Woodward called on G. W. Quick to present the paper "Atmospheric Exposure and Laboratory Tests on Non-Ferrous Screen Wire Cloth" appended to the report. On motion, the report of the committee was adopted.

A paper entitled "A Study of the Error of Averages and Its Application to Corrosion Tests" by C. H. Humes, R. F. Passano and Anson Hayes was presented by Mr. Hayes.

The report of the Sectional Committee on Specifications for Zinc Coating of Iron and Steel was presented by the chairman, J. A. Capp. The adoption as an A.S.T.M. standard of the Tentative Specifications for Zinc (Hot-Galvanized) Coatings on Structural Shapes, Plates and Bars and Their Products (A 123 – 29 T) was approved for reference to letter ballot of the Society and the recommendation that the specifications be referred to the American Standards Association for approval was accepted.

It was announced that Technical Committee II on Sheet and Sheet Products of the sectional committee had voted to recommend to the sectional committee that the A.S.T.M. Standard Specifications for Zinc-Coated (Galvanized) Sheets (A 93 – 27) be submitted to the American Standards Association for approval. It is proposed that a meeting of the sectional committee be held as soon as practicable and if the recommendation of Technical Committee II is then approved and the subsequent letter ballot of the sectional committee is favorable, the Society will be requested to submit the specifications to the American Standards Association for approval. This method of procedure was approved. On motion, the report of the sectional committee was adopted.

A paper entitled "Some Observations on the Outdoor Atmospheric Corrosion of Protective Zinc Coatings" by C. L. Hippensteel, C. W. Borgmann and F. F. Farnsworth, was presented from manuscript by Mr. Hippensteel and discussed.

The meeting then adjourned till 8 p. m.

NINTH SESSION—THURSDAY, JUNE 26, 9.30 A. M.

On Brick, Refractories, Tile, Slate, Stone, Timber, Shipping Containers.

(Held Simultaneously with Eighth Session)

Mr. S. T. Wagner in the chair.

The report of Committee C-8 on Refractories, in the absence of the chairman, G. A. Bole, was presented by the secretary, L. J. Trostel. The proposed revision of the Tentative Definitions of Terms Relating to Refractories (C 71 - 28 T) was accepted, the definitions as revised being continued as tentative. The proposed tentative revision of the Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 - 28) was accepted and approved for publication as tentative. In presenting the report Mr. Trostel called on A. E. R. Westman to present the "Manual for Interpretation of Refractory Test Data (1929)" appended to the report. On motion, the report of the committee was adopted.

The report of Committee C-3 on Brick, in the absence of the chairman, T. R. Lawson, was presented by the secretary, J. W. McBurney. The proposed immediate revision of the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 - 29) was unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

The proposed revision of the Tentative Methods of Testing Brick (Compression, Flexure and Absorption) (C 67 - 28 T) was accepted, the specifications as revised being continued as tentative.

The advancement to standard of the Tentative Specifications for Sand-Lime Building Brick (C 73 - 28 T), as revised, and the Tentative Specifications for Paving Brick (C 7 - 29 T) without revision was approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

A paper entitled "Some Results of Freezing-and-Thawing Tests Made with Clay Face Brick" by L. A. Palmer and J. V. Hall was presented by Mr. Palmer and discussed.

The report of Committee C-4 on Clay and Cement-Concrete Pipe was presented by the chairman, G. T. Hammond. The proposed Tentative Specifications for Reinforced-Concrete Pipe and Specifications for Reinforced-Concrete Culvert Pipe were accepted for publication as tentative. The withdrawal of the Tentative Specifications for Required Safe Crushing Strength of Sewer Pipe to Carry Loads from Ditch Filling (C 15 – 17 T) was approved. On motion, the report of the committee was adopted.

The report of Committee C-6 on Drain Tile, in the absence of the chairman, Anson Marston, was presented by D. G. Miller. On motion, the report of the committee was adopted.

The report of Committee C-10 on Hollow Masonry Building Units was presented by the chairman, D. E. Parsons. The advancement to standard of the tentative revisions of the Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27) and for Hollow Burned-Clay Floor Tile (C 57 – 27) was accepted and approved for reference to letter ballot of the Society for adoption.

The proposed immediate revision of the Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27) was unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

The advancement to standard of the Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 – 28 T) was approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

A paper entitled "Strength Tests on Roofing Tiles" by Norman W. Kelch, in the absence of the author, was presented from manuscript by J. W. McBurney.

The report of Committee D-16 on Slate was presented by the chairman, W. B. Plank. In presenting the report, Mr. Plank called on H. A. Stacy to present the paper entitled "Chemical Experiments on Acid and Alkali Resistance of Slates" by C. L. Lancaster and C. H. Behre, Jr., appended to the report. On motion, the report of the committee was adopted.

The report of Committee D-18 on Natural Building Stones, in the absence of the chairman, F. Y. Joannes, was presented from manuscript by the secretary, H. S. Brightly. On motion, the report of the committee was adopted.

The report of Committee C-5 on Fire Tests of Materials and Construction, in the absence of the chairman, R. P. Miller, was presented by the secretary, Fitzhugh Taylor. On motion, the report of the committee was adopted.

The report of Committee D-7 on Timber, in the absence of the chairman, Hermann von Schrenk, was presented by the secretary, J. A. Newlin. The proposed Definitions of Terms Relating to Timber Preservatives and the proposed Tentative Method for the Determination of the Specific Gravity, 38°/15.5° C., of Creosote Fractions were accepted for publication as tentative.

The proposed Tentative Specifications for Timber Piles were accepted for publication as tentative to supersede the present Tentative Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted (D 25 – 20), which specifications were accordingly withdrawn.

The revisions proposed for immediate adoption in the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 27), Method of Test for Coke Residue of Creosote Oil (D 168 – 27) and for Distillation of Creosote Oil (D 246 – 28) were unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

The advancement to standard of the Tentative Definitions of Terms Relating to Timber (D 9 – 29 T) to supersede the present Standard Definitions of Terms Relating to Structural Timber (D 9 – 15) was approved for reference to letter ballot of the Society for adoption.

The advancement to standard of the tentative revision of the Standard Specifications for Structural Wood Joist, Planks, Beams, Stringers and Posts (D 245 – 27) was accepted and approved for reference to letter ballot of the Society for adoption.

In presenting the report Mr. Newlin called on S. R. Church to present the report of Subcommittee VI on Timber Preservatives. On motion, the report of the committee was adopted.

The report of Committee D-10 on Shipping Containers was presented by the chairman, J. A. Newlin. On motion, the report of the committee was adopted.

A paper entitled "The Comparative Strength of Short Wooden Beams With and Without Overhang Beyond the Supports," in the absence of the author, F. J. Converse, was presented by title.

The meeting then adjourned till 8 p. m.

TENTH SESSION—THURSDAY, JUNE 26, 8 P. M.

On Non-Ferrous Metals

(Held Simultaneously with Eleventh Session)

Mr. W. Reuben Webster in the chair.

The report of Committee B-1 on Copper Wire was presented by the chairman, J. A. Capp. The revisions proposed for immediate adoption in the Standard Specifications for Round and Grooved Hard-Drawn Copper Trolley Wire (B 47 – 27) and for Bronze Trolley Wire (B 9 – 29) were accepted and unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. On motion, the report of the committee was adopted.

The report of Committee B-2 on Non-Ferrous Metals and Alloys, in the absence of the chairman, William Campbell, was presented by the vice-chairman, W. H. Bassett. In presenting the report Mr. Bassett called on H. A. Anderson to present the report of Subcommittee XV on Die-Cast Metals and Alloys, appended to the report. On motion, the report of the committee was adopted.

A paper entitled "Development of Zinc-Base Die-Casting Alloys" by D. L. Colwell was presented from manuscript by the author.

A paper entitled "Silver Solders" by R. H. Leach was presented by the author and discussed.

The report of Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys was presented by the chairman, Dean Harvey. The proposed Tentative Method of Test for Thermoelectric Power was accepted for publication as tentative.

The advancement to standard of the Tentative Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating (B 70 – 27 T) was approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

The report of Committee B-7 on Light Metals and Alloys, Cast and Wrought, in the absence of the chairman, J. B. Johnson, was presented by the vice-chairman, E. H. Dix, Jr. Since the proposed Tentative Specifications for Aluminum Alloy (Duralumin) Sheet, Specifications for Aluminum-Manganese Alloy Sheet and Specifications for Magnesium-Base Alloy Castings being recommended by the committee for publication as tentative had not been distributed in advance of the meeting, unanimous consent of the meeting was asked for on their acceptance. On motion, the publication of these three specifications as tentative was unanimously approved. On motion, the report of the committee was adopted, subject to a favorable letter ballot of Committee B-7 since the report had not been preprinted and distributed in advance of the annual meeting in time to secure a letter ballot of the committee.[1]

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[1] The report was submitted to letter ballot of the committee, which consists of 28 members; 22 members returned their ballots, of whom 21 have voted affirmatively and none negatively.

The report of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, was presented by the chairman, C. H. Mathewson. The proposed revisions of the Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 29), for Seamless 70 – 30 Brass Condenser Tubes and Ferrule Stock (B 55 – 25), and for Seamless Muntz Metal Condenser Tubes and Ferrule Stock (B 56 – 25) were accepted for publication as tentative.

The proposed revision of the Tentative Specifications for Copper Tubing for Refrigerators (B 68 – 27 T) was accepted, the specifications as revised being continued as tentative.

The advancement to standard of the Tentative Specifications for Seamless Copper Tubes (B 75 – 28 T) without revision was approved for reference to letter ballot of the Society for adoption. On motion, the report of the committee was adopted.

The report of the Special Committee on Promotion of General Use of Specifications for Copper Alloys in Ingot Form was presented by the chairman, G. H. Clamer. On motion, the report of the committee was accepted for publication.

A paper entitled "The Effect of Small Additions of Nickel to a Copper-Tin Bronze" by Clair Upthegrove, G. Wilson and F. N. Rhines was presented from manuscript by Mr. Upthegrove.

A paper entitled "The Significance of Hardness Values for Some Copper-Zinc Alloys" by C. H. Davis and E. L. Munson was presented by Mr. Munson and discussed.

The meeting then adjourned till the following morning.

ELEVENTH SESSION—THURSDAY, JUNE 26, 8 P. M.

On Paints

(*Held Simultaneously with Tenth Session*)

Past-President G. W. Thompson in the chair.

The winners of the Golf and Tennis Tournaments were announced and prizes awarded by E. D. Boyer on behalf of T. R. Lawson, chairman of the Entertainment Committee. The A.S.T.M. Championship Golf Cup for low score was won by H. V. Churchill of the Aluminum Co. of America. The A.S.T.M. Championship Tennis Cup was won for the second time by R. J. McKay of the International Nickel Co.

Other prize winners in the golf and tennis tournaments were: J. J. Howard, W. L. Holter, F. M. Hartley, F. H. Morehead, C. N. Conner, W. M. Kinney, L. J. Markwardt, W. C. Bruce, M. A. Swayze, H. A. Sawyer, J. McE. Sanderson, R. L. Moore.

The report of Committee D-1 on Preservative Coatings for

Structural Materials, in the absence of the chairman, Allen Rogers, was presented by the vice-chairman, H. A. Gardner.

The proposed Tentative Specifications for Glazier's Putty, for Amyl Alcohol (Synthetic), for Amyl Acetate (Synthetic), for Butyl Propionate (90 to 93 per cent Grade) and for Ethyl Lactate (Synthetic) were accepted and approved for publication as tentative.

The revisions recommended for immediate adoption in the Standard Specifications for Lampblack (D 209 - 26), in the Specifications for Bone Black (D 210 - 26) and in the Methods of Routine Analysis of White Pigments (D 34 - 27) were unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

The proposed revisions of the following tentative standards were accepted, the methods and specifications, as revised, being continued as tentative:

Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (D 268 - 29 T).

Tentative Specifications for:

- Soluble Nitrocellulose (D 301 - 29 T);
- Ethyl Acetate (85 to 88 per cent Grade) (D 302 - 29 T);
- Butyl Acetate (85 to 99 per cent Grade) (D 303 - 29 T);
- Butanol (Normal Butyl Alcohol) (D 304 - 29 T).

The advancement to standard of the Tentative Methods of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (D 307 - 29 T) was approved for reference to letter ballot of the Society for adoption.

The withdrawal of the Standard Specifications for Dry Bleached Shellac (D 207 - 26), for Orange Shellac (D 237 - 27) and of the Standard Methods of Testing Shellac (D 29 - 25) and for Determination of Wax in Shellac (Machine Made and Dry-Bleached Refined Shellac) (D 29 - 28) was approved. On motion, the report of the committee was adopted.

A paper entitled "Procedure Used by the Forest Products Laboratory for Evaluating Paint Service on Wood," by F. L. Browne, in the absence of the author, was presented by title.

A paper entitled "Paint Failure Diagnosis," by Robert Job, was presented by the author.

The subject of hiding power of paints was covered by the following four papers:

"Hiding Power Measurements in Theory and Application" by A. H. Pfund—presented by the author;

"A Discussion of Hiding Power and Its Measurement" by G. F. A. Stutz, Jr., and G. S. Haslam—presented by Mr. Stutz;

"A Practical Brush-Out Test for Hiding Power of Paints" by H. A. Gardner, G. G. Sward and S. A. Levy—presented by Mr. Gardner;

"Hiding Power and Tinting Strength of White Pigments" by R. L. Hallet—presented from manuscript by the author.

The presentation of these papers was followed by discussion.

A paper "Gloss and Its Quantitative Measurement" by E. D. Ries and C. B. Gilbert was presented from manuscript by Mr. Ries and discussed.

A paper entitled "A Method for the Determination of the True Acid Value of Oils, Varnishes, Liquid Driers and Soaps" by E. W. Diener and S. Werthan was presented by Mr. Diener.

The meeting then adjourned till the following morning.

TWELFTH SESSION—FRIDAY, JUNE 27, 9.30 A. M.

On Naval Stores—Rosin

(Held Simultaneously with Thirteenth Session)

Vice-President K. G. Mackenzie in the chair.

The report of Committee D-17 on Naval Stores was presented by the chairman, F. P. Veitch. The Tentative Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark) (D 269 - 27 T) was approved for reference to letter ballot of the Society for adoption as standard. On motion, the report of the committee was adopted.

Mr. Mackenzie then invited F. P. Veitch to preside over the Symposium on Rosin.

Mr. Veitch in introducing the symposium on rosin stated that rosin is one of the important raw materials in a number of industries; and that this country is the largest producer of rosin, producing about 60 to 70 per cent of the total rosin made in the world. Although rosin has been used for many years for a number of purposes, unfortunately there are not sufficient reliable data with regard to rosin and it has been the hope of Committee D-17 on Naval Stores that through this symposium it might be possible to get information that is available to those interested in the use of rosin.

The uses of rosin in a number of materials were covered in the following papers:

"Rosin in the Manufacture of Rosin Esters" by Stephen Babcock—presented from manuscript by the author;

"Rosin in Paints and Varnishes" by F. W. Hopkins—presented by the author;

"Rosin as a Linoleum Component" by M. K. Bare—presented by the author;

"Rosin and Rosin Oil in Rubber and Reclaimed Rubber" by H. A. Winkelmann and E. B. Busenburg—presented from manuscript by Mr. Winkelmann;

"Rosin in Cable Impregnating Compounds" by J. P. Millwood —presented by the author;

"The Use of Rosin in Insecticides and Disinfectants" by R. C. Roark—in the absence of the author presented by C. F. Speh;

"Rosin Used to Produce Rosin Oil" by V. E. Grotlisch—presented by the author;

"The Use of Rosin in Core Oil" by Werner G. Smith—in the absence of the author, presented by title.

The presentation of these papers was followed by discussion.

The meeting then adjourned till 2 p. m.

THIRTEENTH SESSION—FRIDAY, JUNE 27, 9.30 A. M.

Symposium on Aircraft Materials

(Held Simultaneously with Twelfth Session)

President T. D. Lynch in the chair.

The Symposium on Aircraft Materials was introduced by Mr. Horace C. Knerr, who stated that the recently established aircraft industry was expanding very rapidly and that there is perhaps no industry in which an exact knowledge of the properties of materials of construction is more necessary. Since each individual part must be dependable and of the lowest possible weight, it is essential to know the service each type and class of material can be depended upon to render and to insure that each unit will perform satisfactorily. This requires complete and accurate engineering data, thorough testing and adequate standard specifications to insure that the requirements are met. It was with this thought in mind that the Advisory Committee was appointed to assist the Committee on Papers and Publications in arranging the symposium program and in securing authors for a group of papers each dealing with some topic of major importance in aircraft materials and testing problems rather than design features. It was hoped in this compendium to contribute to the aircraft industry a small reference volume of authentic information of timely and reasonably permanent value.

President Lynch introduced Mr. Knerr as chairman of the committee in charge of the symposium who then took the chair.

The subjects of ferrous metals, structural and engineering light alloys and high-alloyed steels in aircraft construction were covered in the following papers:

"Ferrous Metals Used in Airplane Construction" by J. B. Johnson—presented by H. A. Backus;

"Structural and Engineering Light Alloys for Aircraft" by R. L. Templin, F. V. Hartman and E. C. Hartmann—presented by Mr. Templin;

"The Highly-Alloyed Steels in Aircraft Construction" by Jerome Strauss—presented by the author.

The presentation of these papers was followed by discussion.

A paper entitled "Strength and Characteristics of Wood Used in Aircraft Construction" by G. W. Trayer, in the absence of the author, was presented by L. J. Markwardt and discussed.

A paper entitled "Aeronautical Textiles" by W. E. Emley, in the absence of the author, was presented by title.

The subjects of corrosion-prevention methods in aircraft construction and aircraft finishes were covered in the following papers:

"Corrosion-Prevention Methods as Applied in Aircraft Construction" by H. S. Rawdon— presented by the author;

"Notes on Aircraft Finishes" by H. A. Gardner—presented by the author.

The presentation of these papers was followed by discussion.

A paper entitled "Applications of Stampings, Forgings and Castings in Aircraft Construction" by H. G. Runde was presented by the author and discussed.

The meeting then adjourned till 2 p. m., the symposium being continued in the Fourteenth Session.

FOURTEENTH SESSION—FRIDAY, JUNE 27, 2 P. M.

Symposium on Aircraft Materials (continued from Thirteenth Session)

(Held Simultaneously with Fifteenth Session)

Mr. Bradley Stoughton in the chair.

The Symposium on Aircraft Materials which had been opened in the Thirteenth Session was continued in this session.

The subject of aircraft engines was covered in two papers as follows:

"Materials of Construction in Aircraft Engines" by R. R. Moore —presented by the author;

"Failures of Aircraft Engine Parts and Causes Thereof" by T. T. Neill—presented by the author.

The presentation of these papers was followed by discussion.

The subjects of specifications and materials control and mechanical testing of aircraft materials were covered by the following papers:

"Specifications and Materials Control" by H. A. Backus—presented by the author;

"Mechanical Testing of Aircraft Materials" by J. B. Johnson—in the absence of the author presented by H. A. Anderson.

The presentation of these papers was followed by discussion.

The welding of aircraft materials was covered by two papers as follows:

"Metal Joints in Aircraft Construction" by T. W. Downes—presented by the author;

"Procedure Control in Aircraft Welding" by H. L. Whittemore, J. J. Crowe and H. H. Moss, in the absence of the authors was presented by H. K. Seeman.

The presentation of these papers was followed by discussion.

A paper entitled "X-ray Testing of Aircraft Materials" by Ancel St. John in the absence of the author was presented by H. R. Isenburger and discussed.

A paper entitled "Photo-Elastic Studies of Aircraft Parts" by T. H. Frost, in the absence of the author was presented by title.

A paper entitled "Heat Treatment of Aircraft Parts" by H. C. Knerr was presented by the author and discussed.

The meeting then adjourned till 8 p. m.

FIFTEENTH SESSION—FRIDAY, JUNE 27, 2 P. M.

On Gypsum, Cement, Concrete

(Held Simultaneously with Fourteenth Session)

Mr. G. E. Warren in the chair.

The report of Committee C-11 on Gypsum, in the absence of the chairman, J. W. Ginder, was presented by the vice-chairman, H. E. Brookby. The proposed Tentative Specifications for Gypsum Sheathing Board were accepted for publication as tentative.

The immediate revision of the Standard Specifications for Calcined Gypsum (C 23 – 22), for Gypsum Plasters (C 28 – 27), for Gypsum Plaster Board (C 37 – 25), for Gypsum Molding Plaster (C 59 – 29), for Gypsum Pottery Plaster (C 60 – 29) was unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote.

In respect to the revisions of the Standard Methods of Testing Gypsum and Gypsum Products (C 26 - 27), the committee recommended changes in the revisions as preprinted as follows:

Section 21.—Change the fifth sentence from its present form: namely,

> When sufficiently hard, remove and store in the room at a temperature of not less than 15.6° C. (60° F.) nor more than 37.8° C. (100° F.) for at least seven days.

to read as follows:

> Retain briquets in molds in moist air (not less than 24 hours) until thoroughly hardened. Remove from molds and store specimens in the room at a temperature of not less than 21.1° C. (70° F.) nor more than 37.8° C. (100° F.) to complete a minimum 7-day aging period.

Section 22.—Change the fifth sentence from the following form as preprinted:

> When sufficiently hard, remove and store in the room at a temperature of not less than 15.6° C. (60° F.) nor more than 37.8° C. (100° F.) for at least seven days, and by weighing once a day, when the weight has become constant to within 0.1 per cent, proceed to test the specimens in a standard testing machine used for the determination of compressive strength.

to read as follows:

> Retain cubes in molds in moist air (not less than 24 hours) until thoroughly hardened. Remove from molds and store specimens in the room at a temperature of not less than 21.1° C. (70° F.) nor more than 37.8° C. (100° F.) to complete a minimum 7-day aging period. Weigh once a day and when the weight has become constant to within 0.1 per cent, proceed to test the specimens in a standard testing machine used for the determination of compressive strength.

With these modifications, the revisions were unanimously approved, subject to subsequent letter ballot of the committee, for reference to letter ballot of the Society for adoption.[1]

The advancement to standard of the Tentative Specifications for Keene's Cement (C 61 - 29 T) and for Calcined Gypsum for Use in the Preparation of Dental Plasters (C 72 - 29 T) with revisions was approved for reference to letter ballot of the Society for adoption.

In addition to the recommendations concerning standards and tentative standards appearing in the report as preprinted the committee recommended the following revision for immediate adoption of the Standard Specifications for Gypsum Plastering Sand (C 35 - 25) that had been inadvertently omitted from the report:[2]

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[1] The subsequent letter ballot on this recommendation resulted as follows: 27 affirmative, 1 negative, with 4 members not voting.

[2] These revisions have been incorporated in the Report of Committee C-11 on Gypsum as published in these *Proceedings*, see p. 711.

Section 2.—Change from its present form: namely,

2. It shall be graded from fine to coarse, and when dry not more than 6 per cent by weight shall be retained on a No. 8 (2380-micron) sieve; not less than 80 per cent by weight shall be retained on a No. 50 (297 micron) sieve; and not more than 6 per cent by weight shall pass a No. 100 (149-micron) sieve. These sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials.

to read as follows:

2. Gypsum plastering sand shall be graded from fine to coarse within the following limits:

	PERCENTAGE RETAINED	
	MAXIMUM	MINIMUM
Retained on a No. 4 (4760 micron) sieve	0	..
Retained on a No. 8 (2380 micron) sieve	10	0
Retained on a No. 30 (590 micron) sieve	80	15
Retained on a No. 50 (297 micron) sieve	95	70
Retained on a No. 100 (149 micron) sieve	..	95
Weight removed by decantation	not more than 5 per cent	

The sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.

Since these revisions had been approved in regular manner by the committee, by unanimous action they were accepted for reference to letter ballot of the Society for adoption. The letter ballot on this recommendation resulted in 27 affirmative and 1 negative votes with 4 members not voting. On motion, the report of the committee was adopted.

The report of Committee C-1 on Cement was presented by the chairman, P. H. Bates. The revision proposed for immediate adoption in the Standard Specifications and Tests for Portland Cement (C 9 – 26) was unanimously approved for reference to letter ballot of the Society for adoption, this recommendation requiring a nine-tenths vote. On motion, the report of the committee was adopted.

A paper entitled "The Rate of Hydration of Cement Clinker: Part II—Portland Cement at Nine and Twelve Months; Part III—Three Minerals Found in Portland Cement" by F. O. Anderegg and D. S. Hubbell was presented by Mr. Anderegg and discussed.

A paper entitled "A Study of Fourteen Brands of Standard Portland Cements and Four Early-Strength Cements" by C. H. Scholer and L. H. Koenitzer was presented by Mr. Koenitzer and discussed.

A paper entitled "The Relation Between the Strengths of Cements Developed by Mortar Specimens and Concrete Specimens" by J. R. Dwyer and P. H. Bates was presented by Mr. Dwyer and discussed.

A paper entitled "Strength and Resistance to Sulfate Waters of Concrete Cured in Water Vapor at Temperatures Between 100 and 350° F." by Dalton G. Miller was presented by the author and discussed.

A verbal report of the progress of the Sectional Committee on Specifications for Plastering, in the absence of the chairman, A. O. Lynas, was presented by the Assistant Secretary.

The meeting then adjourned till 8 p. m.

SIXTEENTH SESSION—FRIDAY, JUNE 27, 8 P. M.

On Concrete

Mr. H. S. Mattimore in the chair.

An informal report of progress of the activities of Committee C-2 on Reinforced Concrete, in the absence of the chairman, S. C. Hollister, was presented by the secretary, W. A. Slater.

The report of Committee C-9 on Concrete and Concrete Aggregates was presented by the chairman, Cloyd M. Chapman. The proposed Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading was accepted and approved for publication as tentative.

The advancement to standard, with revisions, of the Tentative Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 – 28 T), for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 – 28 T) and for Field Determination of Surface Moisture in Fine Aggregate (C 70 – 28 T) was approved for reference to letter ballot of the Society for adoption.

The report as preprinted had recommended that the tentative revision proposed in 1929 in the Standard Method of Making and Storing Specimens of Concrete in the Field (C 31 – 27) be advanced to standard with a further revision of Section 7. The report as printed was in error, since the committee wished this tentative revision to be continued as tentative for another year with the modification recommended in the revision of Section 7. The modification was accepted and the revision as modified continued as tentative.

In presenting this voluminous report the chairman reviewed very briefly the activities of the various subcommittees and called upon the various subcommittee chairmen and authors to present their individual reports and papers, appended to the report, as follows:

"Testing Concrete Cylinders Using Confined Sand Cushion" by D. D. McGuire—presented by the author;

"Method of Capping Concrete Cylinders Using Sulfur Compound" by P. J. Freeman—presented by the author;

"Suggested Procedure for Testing Concrete in Which the Aggregate is More Than One-Fourth the Diameter of the Cylinders" by F. R. McMillan—briefly described by Mr. Chapman;

"Abrasion of Aggregates" by F. H. Jackson—presented by the author;

"One-Year Tests on the Effect of Dust-Coated Stone on the Properties of Concrete" by A. T. Goldbeck—presented by title;

Report of Section on Relation Between the Abrasion Loss on Blast-Furnace Slag and Its Concrete-making Properties—presented by Fred Hubbard;

"Study of Methods for Determining Moisture in Sand" by S. H. Graf and R. H. Johnson—presented by Mr. Graf;

"Apparatus for Flexural Tests of Concrete Beams" by A. T. Goldbeck—presented by title;

Bibliography on Mixing Concrete—presented by title;

"Band Type Circumferential Extensometer for Poisson's Ratio Determinations" by C. H. Scholer—presented by the author;

"Digest of Tests in the United States for the Determination of the Modulus of Elasticity of Portland-Cement Mortar and Concrete" by L. W. Teller—presented by title;

"Digest of Test Data on Poisson's Ratio for Concrete" by F. E. Richart and N. H. Roy—presented by title;

"A Summary of Investigations of Volume Changes in Cements, Mortars and Concretes Produced by Causes Other than Stress" by R. E. Davis—in the absence of the author presented by title;

The report of Subcommittee XVII on Conditions Affecting Durability of Concrete in Structures—presented by title.

On motion, the report of the committee was adopted.

A motion expressing appreciation for this valuable report and complimenting the officers of the committee, as well as all the members of Committee C-9, was unanimously adopted.

A paper entitled "Further Studies on the Workability of Concrete" by W. F. Purrington and H. C. Loring was presented from manuscript by Mr. Purrington and discussed.

A paper entitled "Tests of Plain and Reinforced Haydite Concrete" by F. E. Richart and V. P. Jensen was presented by Mr. Richart and discussed.

A paper entitled "Flow of Concrete Under Sustained Compressive Stress" by R. E. Davis and H. E. Davis, in the absence of the authors, was presented by F. E. Richart.

A paper entitled "Variations of Compressive Strength of Concrete Within the Water-Cement Ratio Law" by Ira L. Collier was presented by the author and discussed.

The Assistant Secretary read a telegram of greetings from 40 members of the Society meeting under the auspices of the Southern California District Committee.

Mr. Ira L. Collier was called on to extend the greetings of the Seattle District Committee of which he is chairman.

A paper entitled "Volume Change of Concrete" by C. H. Scholer and E. R. Dawley was presented from manuscript by Mr. Dawley and discussed.

There being no further business, the chair declared the Thirty-third Annual Meeting adjourned *sine die*.

ANNUAL ADDRESS BY THE PRESIDENT

T. D. Lynch

June 25, 1930

We are celebrating today the twenty-eighth anniversary of the American Society for Testing Materials—the thirty-second if we count the four years duration of the American Section of the International Association for Testing Materials. The Society was incorporated in 1902 by seven men of vision. Many of us here present had the honor and pleasure of knowing these men and we revere them for the spirit shown in their lives and in their interest in our Society. They organized it for a very definite purpose, "the promotion of knowledge of the materials of engineering and the standardization of specifications and the methods of testing."

That this purpose is of unbounded significance has been made evident through the importance that materials and knowledge concerning them have assumed in this present age. We have had given to us in nature certain elements which taken collectively or in combination make up the material universe as we know it. These materials represent to us potentialities and it becomes our mission to study and direct the processing of them if we are to change these natural materials and render them serviceable to man. The carrying on of the work of developing further and more exact knowledge concerning these materials has been handed down to us as a legacy worthy of our support and best efforts. We may be proud in having had a part in securing a better understanding of our materials, of advancing the knowledge of them and of leading in developing standard specifications for them.

Materials and adequate specifications therefor are fundamental needs in all engineering, whether they fall under civil, mechanical, electrical, aeronautical or mining engineering, in short, all engineering applications. In fact, engineering has been defined as the science of increasing the usefulness of the raw materials given to us in nature so that they may be productive of greater service to mankind. And the first need in increasing the usefulness of raw materials is to have adequate knowledge concerning their properties. But in arriving at such knowledge through extensive research along many lines, we must be prepared to do it scientifically. We must have accurate measuring units to unveil the hidden mysteries, and many details must be investigated.

For example, in the ever-present demand for more power out of a pound of coal—that is, the striving for greater efficiency—we must have better combustion, accurate gas knowledge and application study. Greater efficiencies have led to superheated steam and higher pressures, requiring definite knowledge of the strength of materials at high temperatures to resist safely the increased steam pressures. The study of materials under these conditions makes it necessary to use refinements of temperature and mechanical measurement, together with their control, for we must know the properties of the materials under the conditions of service. To accomplish this our research investigators are now equipped to make linear measurement to the millionth of an inch and to control temperatures for long periods to within 1° C., and for short periods to a much closer degree. Along electrical lines we are prepared to study the materials under electric arcing or under the action of lightning, demanding measuring devices to measure and record the happenings during a lightning discharge or the arcing over of a circuit breaker on a high-power line under electric surge. The cathode-ray oscillograph in which time can be accurately recorded to a fraction of a millionth of a second provides the means. With these recent developments at our command to measure space to a millionth of an inch, time to a fraction of a millionth of a second and with such accurate temperature control, we have the tools with which to develop new knowledge about our materials and their appropriate application.

As the science of engineering advances, the tendency is to stress materials higher and higher to meet new developments and economic conditions, until the usual factors of safety become so narrow that the modern designers must know by experiment just what stresses and for what length of time materials will endure the loads to be applied—whether they be for short or long periods, whether they be static, impact or reversed stresses, or whether the materials be used at temperatures that are very high or very low. The development of new materials or a different treatment of old materials may be the answer. But these demands keep us ever alert to be prepared for the future.

Materials engineers are expected to know and are asked to advise on these new applications whether they be along physical, chemical, electrical or magnetic lines. No successful business can continue to prosper without looking ahead and carrying on experimental work. Management must not overlook the fact that adequate provision for present needs is not enough but that some research work must be carried out and be given due support. Research may often find an equivalent product at a lower cost, a better product at the same cost, or even a better product at a lower cost due to a by-product resulting that may more than pay for the extra operation. Research leads to progress. Scientifically investigated, the curiosities of yesterday may through investigation and development become the necessities of tomorrow. Researches develop new and brighter light that we may see deeper into the mysteries about us, often changing that which seemed to be a miracle into a common reality. We may realize in the words of Emerson that there is "no truth so sublime but that it may be trivial tomorrow in the light of new thought," and we may also add that that which seems trivial today may be all-important tomorrow.

The American spirit of accepting and using new information as it is brought forward prepares the way for greater developments and finally to standards of the highest order. Standardization has been defined as "common sense applied to creative individualism for the purpose of achieving the greatest good for all." The Society conceives as one of its purposes the development of suitable standards when once the necessary information concerning the materials in question is available. It is difficult for us to realize the utter lack of standard specifications and standard methods of testing in existence at the time the Society was formed. Practically the only specifications then in use were those prepared independently by a limited number of individual companies such as a certain few railroads, manufacturers and contractors. These specifications were quite inadequate. Processes of manufacture were not well established, methods of testing were primitive and standards were yet to be developed. Today we have gone very far along the way of standardization, and in this respect, our Society has been very helpful because of its constitution representing, as it does, industry in all its phases.

The Society's conception of its standardization work is no doubt in large measure responsible for its success and growth since its organization. From a membership of 175 members it has grown to a membership of over 4300. The technical work largely carried out in standing committees has been paralleled by the growth of the committee structure, so that at present we have 87 active committees with a committee membership of almost 2400. Through the efforts of these committees the Society now has 564 standards and tentative standards. This convention will add its quota to the number. That the Society's specifications in general are fulfilling their purpose, has been proved by their general adoption in industry and the further approval of many of them as American Standard by the American Standards Association.

Our Society is peculiarly constituted to represent industry of every kind and in all its branches because its membership extends to every type of industry. The Society's plan for carrying out its work, namely, that of developing information and later the formulation of standard specifications and methods of test, has stood the test of time. The principal factor in this plan is the use of standing committees. These committees or groups of men are composed of a balanced membership in a true sense. By this is meant that producer and consumer and those having a general interest with reference to the problem assigned are included, so that every phase of the problem is represented. These committeemen are selected because of their affiliations, their knowledge, and their willingness to help by contributing to the work their knowledge and experience.

Standard specifications and test methods are therefore developed by presenting the discussions of these men in open meeting, which insures the bringing out of relative facts much more readily and with a greater degree of accuracy than by any other known method. Frequently in these committee meetings differences of opinion and spirited discussion may arise, but ultimately an agreement is reached that is of mutual advantage and to the best interest of industry. The object kept before these committeemen is to establish standards that are right and just in principle and yet commercial. The questions are decided not by personal opinion but by facts. All members work toward a common purpose, though each has his own individual point of view. This insures that specifications so prepared are well considered from the standpoint of both producer and consumer. The committee reports indicate the care and thoroughness with which the committees have done their work, including researches and the embodiment of these researches in the standards drawn.

This cooperative work within committees has proved very effective, and this is augmented by the joint efforts of two or more committees of related interests and also by their cooperation with committees of other socieites.

It is a privilege to see the unselfish manner in which these committeemen work, and to work with them is a joy. We believe with Elbert Hubbard that "It is one of the most beautiful compensations of life that no man can sincerely try to help another without helping himself." Our committee work has proved the truth of this statement. Joint work of this sort helps every member of the group, and while we help others by group work we also help ourselves, our commercial interests and make progress for the human race.

ANNUAL REPORT OF THE EXECUTIVE COMMITTEE

SUMMARY

The year closing with this annual meeting has been an active one, with many important accomplishments in our committee work as recorded in the reports on the program of the meeting. The organization of Committee E-10 on Standards has provided an important administrative arm of the Society for directing standardization activities and is perhaps the outstanding administrative development of the year.

The membership of the Society shows a better net gain during the year, 111, than for several years previously. The membership on June 1, 1930, was 4355. It is believed that the period of transition following the increase of dues of company members has been passed and that a steady growth of membership will now be experienced.

Two new committees have been authorized during the year. One of these will be organized during the annual meeting as Committee B-6 on Die-Cast Metals and Alloys, taking over the activities heretofore carried on by Committee B-2 through its subcommittee on this subject. It has been decided that Committe B-2 will retain under its jurisdiction the work on white metals, such as babbitt, solder and type metals, thus modifying in that particular the comprehensive plan for reorganizing the Society's committee work in the field of non-ferrous metals and alloys.

The second new committee will deal with Mortars for Unit Masonry and it is expected will be organized next fall.

The regular publications of the Society for 1929 comprised 2659 pages, in addition to which the *Book of Tentative Standards* (901 pages) was furnished to members on order at special prices, making a total of all publications, not including preprints and reprints, of 3560 pages. The Index to A.S.T.M. Standards and Tentative Standards was published for the second year and has taken a very definite place as a publication of much value to the members.

Two publications early this year of special interest are the twelve papers that comprised the Symposium on Developments in Automotive Materials at the Regional Meeting in Detroit, which are to be collected with discussion in the form of a single bound pamphlet as a permanent record of the proceedings of that meeting; and a pamphlet entitled "Selected A.S.T.M. Standards for Students" in which has been collected a number of specifications and methods of test for use as a text or reference in the technical schools. In the few months since it has been issued, this pamphlet has made a very definite appeal to the heads of engineering schools throughout the country and it has been necessary to print a second edition to meet requirements next fall.

The Executive Committee has concluded that this pamphlet will be an extremely useful publication to the student members of the Society—possibly more so than the complete *Book of Standards*. It has accordingly decided to recommend to the Society that the annual dues of student members be changed from $3 to $1.50 by amendment of Article VII, Section 1, of the By-laws, with the understanding that the pamphlet of selected standards instead of the *Book* *of Standards* will be supplied to student members. They will at the same time receive a List of Standards and will have the privilege of obtaining copies of either or both parts of the *Book of Standards* at $2 per part. Other privileges at present offered to student members will be continued.

The finances of the Society are in a very satisfactory condition. The surplus at the close of the fiscal year, December 31, 1929, was $37,149.97, in addition to which there are special funds totaling $19,438.05 covering Life Membership Fund, A.S.T.M. Research Fund, Headquarters Fund and Publications Fund. The sum of $12,012.80 is held as reserve for the *1930 Book of Standards*. Investments of Society funds total $54,707.09. The A.S.T.M. Research Fund has now reached the total of $8387.85.

The Society's budget for 1930 anticipates an income, exclusive of investments matured and sold, of $132,000, to which will be added the reserve from 1928 and 1929 income of approximately $12,000 toward the cost of the *Book of Standards*. The current year, 1930, will be an especially heavy one as to volume of publications, the total estimated disbursements being $76,250.

The Executive Committee has renewed the lease on the Society's headquarters in the building of the Engineers' Club of Philadelphia for two years ending December 31, 1931, at a rental of $3000 per year, with an option of extending the lease at the same rental for an additional one or two years. Since it may only be a question of time at the present rate of growth of the Society's work when consideration will need to be given to the procuring of more adequate quarters, the Executive Committee is studying several possibilities.

The first Regional Meeting to be sponsored by the Society was held in Detroit on March 19, 1930, under the auspices of the Detroit members. Devoted to a Symposium on Developments in Automotive Materials, and closing with an informal dinner, the meeting was a success in every way and has a significance in Society affairs far beyond the immediate purposes. The Group Committee Meeting was held in conjunction with the Regional Meeting, and both in attendance and in work accomplished by the committees surpassed any previous meeting.

Relationship to Society work of members on the Pacific Coast has been studied during the year through discussions with the district committees of Southern California, Northern California and Seattle. A correspondent member of the Committee on Papers and Publications has been appointed from each district and the three committees have been invited to review all phases of committee work of the Society of interest to them and to make suggestions for appointments to standing committees. A plan of representation on committees of groups of members on the Coast interested in particular materials is being considered. Membership extension work has been assigned to the three district committees.

The work of the American Standards Association has been developed along satisfactory lines since the reorganization in 1928. The submission of A.S.T.M. Standards to the American Standards Association for approval as American Standard is to be expedited as much as conditions will permit and administration of this work has been placed in the hands of Committee E-10 on Standards. Particularly significant is the organization of two new sectional committees, one on Specifications for Plastering under the joint sponsorship of the American Institute of Architects and the Society, and the other on Fuel Oils under A.S.T.M. sponsorship.

American participation in international consideration of engineering standards has been advanced through the recently acquired membership of the American Standards Association in the International Federation of National Standardizing Associations (I.S.A.). The Society's policy in international standardization work is set forth in some detail later in the report. An interesting development is the establishment of cooperative relations with the German Society for Testing Materials in the study of methods of test of petroleum products and lubricants.

The officers and Permanent Committee of the New International Association for Testing Materials are engaged in developing the program for the next International Congress on Materials to be held in Zurich in 1931. The Society is cooperating in the development of these plans.

Membership:

The membership of the Society on June 1, 1930, was 4355 compared with the membership on the corresponding date a year ago of 4244. Statistics are shown in the following table:

Class of Members	Membership			Losses			Additions		Totals		
	June 1, 1929	June 1, 1930	Resignations	Dropped	Death	Transfer	Transfer	Elections	Loss	Gain	Increase
Honorary	4	4	..	..	..	..	..	..	..	..	..
Life or Perpetuity	11	11	..	..	..	..	..	..	..	..	..
Company, Firm, etc.	1153	1175	55	16	..	3	5	91	74	96	22
Individual, etc.	3018	3090	140	91	9	5	23	294	245	317	72
Junior	58	75	4	4	..	20	..	45	28	45	17
Total	4244	4355	199	111	9	28	28	430	347	458	111
Student	260	249	18	113	..	18	..	138	149	138	11[a]

[a] Decrease.

The number of new members for the year, 430, is greater than for the preceding year (365), and the net gain for the year, 111, is considerably better than for the past two years. The number of company memberships shows an increase, and it is believed that the period of transition followed the increase of dues of company members two years ago has been passed and that a steady growth of membership will now be experienced. The membership curve from the beginning of the Society's history appears in Fig. 1.

Student membership work has been continued in the thirty engineering and technical schools originally selected for development, although since the first of the year it has been necessary to defer active solicitation because of shortage in the supply of the *Book of Standards*—a principal consideration of student membership. Even with this condition, the number of new student members is slightly greater than for the previous year, but the greater number of members dropped has resulted in a slight net decrease for the year. The number of student members transferred to Junior Membership, 18, is gratifying and compares favorably with the experiences of other technical societies.

An amendment of the By-laws affecting the dues of student members is proposed later in the report.

The Society has suffered loss by death of the following nine members:

	DATE OF MEMBERSHIP
Case, Frank H.	1921
Cushman, Allerton S.	1904
Jennings, Robert E.	1910
Murphy, Oliver G.	1922
Rea, A. S.	1913
Tucker, F. J.	1920
Wilder, Frank A.	1927
Williams, Roger C.	1929
Wilson, O. G., Jr.	1927

Allerton S. Cushman was active for many years in the corrosion studies of the Society, having contributed important papers and serving as chairman of the Committee on Corrosion of Iron and Steel from 1907 to 1913. A. S. Rea served for many years on the Committees on Brick, Concrete and Road Materials; Frank A. Wilder for a number of years was vice-chairman of the Committee on Gypsum; O. G. Murphy was a member of the Textiles Committee; and O. G. Wilson, Jr., served on the Petroleum Products Committee.

The plans for general membership extension are being developed as outlined a year ago. District Committees in Chicago and Detroit and the three on the Pacific Coast at Los Angeles, San Francisco and Seattle are diligently engaged in this work, and the steady efforts of a number of standing committees are effective. Other district committees are to be organized. The interest and support of the entire membership is needed in maintaining a vigorous and healthy growth in Society membership.

A.S.T.M. Committee Activities:

The work of the committees of the Society during the past year has been quite active and a review of this work as pertains to standardization and research activities is now a stated function of Committees E-10 on Standards and E-9 on Correlation of Research, respectively. The annual reports of those two committees this year review these activities briefly and there will be issued next fall a more complete statement of the standardization and research activities of the Society, including matters reported upon at this annual meeting. The report of the Executive Committee on committee activities is therefore confined to brief mention of administrative matters and new committees.

Since the last annual meeting, Committee E-10 on Standards has been organized. The steps leading to the creation of this committee were fully outlined in last year's report and it is only necessary here to state briefly the principal functions of the committee:

1. To promote the standardization work of the Society;

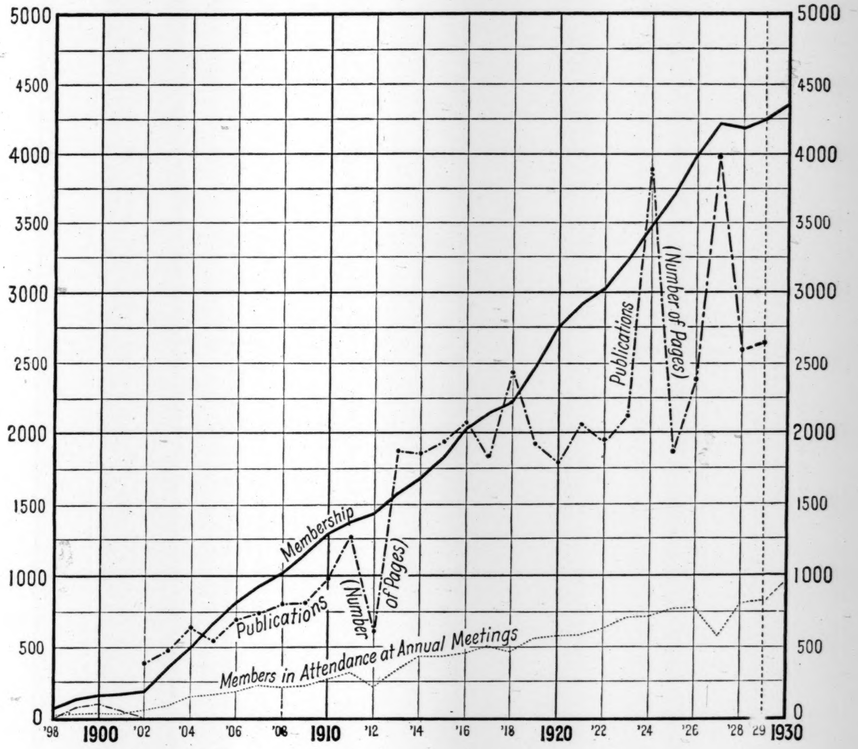

FIG. 1.—Membership and Publications Chart.

2. To consider matters of general policy concerning standardization activities, including relationship with similar activities of other bodies;

3. To consider the desirability of expansion of standardization work into new fields;

4. To review annually the progress in the Society's standardization work; and

5. To pass upon proposed new tentative standards offered between annual meetings of the Society.

The committee also acts in an advisory capacity to the Executive Committee in standardization activities in general.

The Executive Committee appointed the following members to the new committee: Cloyd M. Chapman, T. G. Delbridge, J. H. Gibboney, E. F. Kenney and T. R. Lawson. Mr. Lawson was elected chairman and the Secretary-Treasurer serves *ex-officio* as secretary. The committee's first annual report shows substantial progress in taking hold of administrative problems in this field of the Society's work.

The plan for reorganizing the Society's committee work in the field of non-ferrous metals and alloys, reported in detail a year ago, contemplated the transfer to a new standing committee of the work at present in charge of Subcommittee IV of Committee B-2 on Non-Ferrous Metals and Alloys, covering particularly the white metals such as babbitt and solder metals. Upon further consideration of this detail of the plan and in consultation with the Coordinating Committee on Non-Ferrous Metals and Alloys, it has been decided that it will be best to continue this work under the jurisdiction of Committee B-2, extending the scope to include specifications for type metal.

At the same time, and again upon the advice of the above-mentioned Coordinating Committee, it has been decided to place the Society's work on die-cast metals and alloys in the hands of a new standing committee, which will have the designation Committee B-6 on Die-Cast Metals and Alloys. This work at present is under the jurisdiction of Committee B-2 through its Subcommittee XV. The researches of the subcommittee, which are now leading to the development of specifications, have proved to be very extensive, and the field covered is so large and so important as to justify assignment to a standing committee dealing with this subject alone. The following scope has been provisionally assigned to the new committee: "The accumulation and dissemination of information on and the preparation of specifications for die-cast metals and alloys, including aluminum-base, zinc-base, lead-base, tin-base and copper-base alloys." The Executive Committee has appointed members of the present subcommittee to membership on the new standing committee and has designated the present officers of the subcommittee, namely, H. A. Anderson and P. V. Faragher, to serve respectively as temporary chairman and temporary secretary until formal organization is effected at this annual meeting.

The Executive Committee has also decided to organize a new standing committee on Mortars for Unit Masonry. Development of tests and specifications for such mortars is a matter of especial importance, there being general agreement that the quality of mortar is of great significance in determining the strength and integrity of masonry structures. Various phases of the problem are being studied by certain committees of the Society, but it has been agreed in consultation with these that there is no single A.S.T.M. committee in which the problem as a whole is being or can logically be studied. Committees C-1 on Cement, C-3 on Brick, C-7 on Lime, C-9 on Concrete and Concrete Aggregates, C-10 on Hollow Masonry Building Units and C-11 on Gypsum are interested, being concerned either with materials that enter into the making of mortar or with the masonry units themselves, and each of these committees has been invited to name a representative on the new committee. It is expected that the committee will be organized next fall.

In its report a year ago the Executive Committee mentioned that there were some questions of jurisdiction between Committees B-4 on High-Temperature and Electrical-Resistance Alloys and A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys which were still under consideration. The expansion a year ago of the scope of Committee B-4 to include "high-temperature alloys" seemed to bring about an overlap with the field of work of Committee A-10 and after conference with the two committees the following titles and statements of scope were adopted:

Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys:

Wrought and cast materials and parts for electrical heating and electrical resistance, and for the structure and containers of electric furnaces.

Committee A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys:

Alloys as defined in the title, not falling within the described scope of Committee B-4.

Also, since the work of the two committees is in some fields rather closely related, a joint advisory committee has been formed to coordinate their activities.

In the past year Committee D-2 on Petroleum Products and Lubricants has worked out a plan of organizing "technical committees" for the development of specifications for various petroleum products, as distinguished from its "subcommittee" organization, which is devoted to the writing of test methods. These technical committees, since they deal with specifications, observe the requirements as between producers, consumers and general interests; and Committee D-2 has made the further provision that the chairman shall be a consumer or general interest member. The principal feature of this type of organization is that membership is not to be confined to members of Committee D-2 nor of the Society, this having been decided upon because of the importance of bringing at once into this specification work groups of consumers of petroleum products who heretofore have had little if any occasion to be interested in the general activities of the Society. The plan further contemplates that such technical committees be sufficiently broad in representation, including formally accredited representatives of other organizations, to qualify as sectional committees under the procedure of the American Standards Association—a plan which has particular significance since proposals for standardization of petroleum products on a national scale have already been made. In fact one of the three technical committees originally contemplated, dealing with fuel oils, has been organized as a sectional committee, as mentioned later in the report. The other two, dealing with gasoline and motor oils, have been organized simply as technical committees.

Publications:

During 1929 the usual publications were issued, namely, the ***Proceedings*, *1929 Supplement to Book of A.S.T.M. Standards*,** the ***Year Book*** and the Index to A.S.T.M. Standards and Tentative Standards, comprising the so-called "regular" publications distributed to all members; and the *Book of A.S.T.M. Tentative Standards* as a special publication furnished to members on order. A comparative statement of the volume of these publications during the past four years follows:

	1926, PAGES	1927, PAGES	1928, PAGES	1929, PAGES
Proceedings	1895	1706	2088	1937
Book of A.S.T.M. Standards	....	1871	....	....
Supplement to Book of Standards	102	....	195	293
Year Book (Membership List)	374	398	309	320
Index to A.S.T.M. Standards and Tentative Standards	....	....	95	109
	2371	3975	2687	2659
Book of A.S.T.M. Tentative Standards	1100	824	932	901
	3471	4799	3619	3560

The volume of regular Society publications since 1902 is recorded graphically in Fig. 1.

The Index to A.S.T.M Standards and Tentative Standards was published for the second year and has taken its definite place as a regular publication of much value to the members. The publication is of especial value in acquainting persons with the scope of the Society's standardization work and the extent of what has been accomplished in that field. Five thousand copies are published in addition to those required for distribution to the members, of which over 1000 go to purchasing agents who have asked to receive copies annually.

As in past years, the *A.S.T.M. Bulletin* was issued bimonthly throughout the year; and again the income from advertising, about $4200, was more than sufficient to meet the actual cost of printing and distributing that publication, which was approximately $3900. Advertising in the Index to Standards and Tentative Standards was included for the first time last year, providing an income of $870 towards the total cost of printing and distributing the Index, about $1640.

The sales of the 1927 Book of A.S.T.M. Standards have so far exceeded the estimates upon which the edition of the volume was determined in 1927 that the supply of Part I on Metals is completely exhausted and that of Part II on Non-Metals nearly so. To meet requirements until the 1930 edition is available, the Society has offered to purchase copies of both parts from any members who may be willing thus to dispose of their copies.

A publication matter of especial interest has been the preprinting of the twelve papers that comprised the Symposium on Developments in Automotive Materials held at the Regional Meeting last March in Detroit. These papers comprise approximately 160 pages and are being collected together with discussion in the form of a single bound pamphlet as a permanent record of the proceedings of the Regional Meeting. The expense of publication is being divided equally between Society funds and funds raised by the committee in charge of the Regional Meeting.

An important new publication issued early in 1930 is a pamphlet entitled "Selected A.S.T.M. Standards for Students" in which have been collected some 24 specifications and methods of test with a statement concerning the organization, purposes, membership and standardization procedure of the Society and a résumé of Charles B. Dudley's Presidential Address on "Factors and Principles Involved in the Enforcement of Specifications." The pamphlet has been prepared to meet requests from members of engineering school faculties that the Society publish in convenient form a group of selected A.S.T.M. specifications and methods of test for student use. The pamphlet is not intended to take the place of textbooks but rather to supplement them. It places in the hands of students representative standards that are met with in practice in the form in which they are actually used, so that the student gains specific knowledge of the purpose and the exact wording of specifications necessary to insure that materials of requisite quality are secured. Aside from its strictly educational value the pamphlet will effectively acquaint the future generation of technically trained men with the purposes and activities of the Society and thus build up in a substantial way the membership and strength of the Society for the future.

In the few months since it has been issued the pamphlet has made a very definite appeal to the heads of engineering schools throughout the country. The first printing of 1000 copies has already been sold, the price to students being 50 cents, and a second edition of 2000 copies has been printed. A revised collection of standards will be issued at the end of the year.

Proposed Amendment of the By-laws:

The Executive Committee proposes the following amendment of the By-laws:

Article VII, Dues.—Amend Section 1 to change the annual dues of Student Members from $3 to $1.50.

Coupled with this proposal is a resolution adopted by the Executive Committee, after consultation with the Committee on Papers and Publications, that under the lowered dues the student member shall receive a copy of the "Selected A.S.T.M. Standards for Students" in place of the complete *Book of A.S.T.M. Standards* as at present. It is believed that the pamphlet of selected standards will be a more useful publication for the student than a complete set of standards; and in order that student members may be informed of the complete extent of the Society's work the Executive Committee has further resolved to supply each student member with the List of Standards and to extend to student members the privilege of obtaining copies of either part of the *Book of A.S.T.M. Standards* at the price (at present $2) at which members obtain the second part of that volume in addition to the part to which their dues entitle them, also to obtain copies of separate standards at practically cost price. Other privileges at present offered to student members will be continued, namely, to receive the *Year Book* and *Bulletin*, preprints of all reports and papers upon request, and the opportunity of securing copies of the annual *Proceedings* and other publications at the special prices to members.

Finances of the Society:

Report for Fiscal Year 1929.—The annual statement of the finances of the Society follows in the report of the auditors for the fiscal year, January 1, 1929, to December 31, 1929, which includes the balance

REPORT OF THE AUDITORS

PHILADELPHIA, January 6, 1930.

AMERICAN SOCIETY FOR TESTING MATERIALS,
Philadelphia, Pa.

Dear Sirs:

We respectfully report that we have made an audit and examination of the books and accounts of your Society for the seven months ended December 31, 1929, having previously made a similar audit and report for the preceding five months ended May 31, 1929, and at both audits found the accounts to be correct.

We submit herewith balance sheet as of December 31, 1929, as also a statement of cash receipts and disbursements for the twelve months then ended.

We have verified the transactions set forth in the budget record for the seven months ended December 31, 1929, as also for the five months ended May 31, 1929, as reported in ours of June 13, 1929, and found the same to be correct.

We have verified by actual inspection and count the securities as scheduled under Investments and report all interest collected to December 31, 1929, and all subsequent coupons attached. Respectfully submitted,

(Signed) JOHN HEINS AND CO., *Certified Public Accountants*

BALANCE SHEET AS OF DECEMBER 31, 1929

ASSETS				
Current Funds			$3 683.76	
Investments			54 707.09	
Accounts Receivable:				
For Publications		$1 848.39		
Advertising		1 419.00		
Members, for 1929 Dues		2 927.54		
Members, for Binding		27.00		
			6 221.93	
Furniture and Fixtures			5 896.31	
New International Association for Testing Materials			5.00	
				$70 514.09
LIABILITIES				
Publications paid for in advance		$167.35		
Advertising paid for in advance		32.00		
Members Dues paid in advance		1 015.10		
Members Binding paid in advance		63.00		
Entrance Fees paid in advance		160.00		
			$1 437.45	
Income, A.S.T.M. Research Fund			475.82	
Life Membership Fund	$3 005.20			
A.S.T.M. Research Fund	8 387.85			
Headquarters Fund	5 030.00			
Publications Fund	3 015.00			
Book of Standards Reserve	12 012.80			
		$31 450.85		
Surplus		37 149.97		
			68 600.82	
				$70 514.09

RECEIPTS AND DISBURSEMENTS

JANUARY 1, 1929, TO DECEMBER 31, 1929

Current Funds, January 1, 1929			**$978.56**

RECEIPTS

Current Dues	$80 399.26		
Past Dues	934.44		
Advance Dues	998.65		
Life Membership Dues	300.00		
Income, Life Membership Fund	138.50		
Entrance Fees	3 755.00		
Total Dues		$86 525.85	
Separate Standards	$4 413.39		
Book of Standards	6 016.55		
Book of Standards—Members for both Parts	462.00		
Book of Tentative Standards	7 629.73		
Proceedings	3 755.27		
Miscellaneous (including special reprints)	5 563.85		
Total Sale of Publications		27 840.79	
Binding (Members)		658.00	
Advertising in Bulletin		4 067.50	
Advertising in Index to Standards and Tentative Standards		250.00	
Authors' Reprints		270.36	
Sale of Certificates of Membership		52.50	
Interest on Deposits and Investments		3 650.78	
Accrued Interest and Premium		206.56	
Excess Remittances		207.90	
Investments matured or sold		30 995.31	
Contribution to A.S.T.M. Research Fund		250.00	
Income, A.S.T.M. Research Fund		319.00	
Registration and other fees, Annual Meeting		1 081.50	
Seaview Golf Club (see Disbursements)		164.15	
New Internat. Assn. for Testing Materials, Dues		287.00	
Local Committee Group Meetings		700.00	
Miscellaneous		50.49	
Total Receipts			$157 577.69

DISBURSEMENTS

Publications:			
Year Book	$3 625.99		
Book of Standards	437.93		
Book of Standards Supplement	2 719.64		
Book of Tentative Standards	3 575.74		
Proceedings	26 514.60		
Preprints	4 452.48		
Bulletin and Circulars to Members	5 219.31		
Carried forward		$46 545.69	$158 556.25

Brought forward			$158 556.25
Publications (*Continued*):			
Brought forward	$46 545.69		
Separate Standards	1 991.29		
Index to Standards and Tentative Standards	1 640.54		
Miscellaneous (including special reprints)	2 295.83		
		$52 473.35	
Salaries		37 619.00	
General Office Expenses		7 635.21	
Expenses, Standing Committees		2 287.82	
Expenses, Annual Meeting		2 789.25	
Traveling Expenses—Administrative Committees		2 478.67	
Rent and Insurance, Storage Rooms		321.00	
Rent, Headquarters		2 400.00	
Headquarters Maintenance		784.08	
Furniture and Fixtures		1 224.37	
Certificates of Membership		23.00	
American Standards Association and Sectional Committees		1 906.89	
Investments:			
1930 Book of Standards Reserve	$5 955.00		
Headquarters Fund	1 000.00		
Publications Fund	1 000.00		
A.S.T.M. Research Fund	2 000.00		
Current Funds temporarily invested, matured or sold	30 904.06		
		40 859.06	
Income A.S.T.M. Research Fund		73.18	
U. S. National Committee International Electrotechnical Commission		330.00	
Central Lumber Standards Committee		25.00	
Accrued Interest and Premium		206.56	
Refund of Excess Remittances		207.90	
Seaview Golf Club (see Receipts)		164.15	
New International Association for Testing Materials, Dues		289.00	
Local Committee Group Meetings		700.00	
Miscellaneous		75.00	
Total Disbursements			154 872.49
Balance, Current Funds, December 31, 1929			$3 683.76
Balance accounted for as follows:			
Cash on hand		$683.76	
Liberty Bonds ($4 000), Chesapeake & Ohio R. R. Bonds ($6 000), and Baltimore & Ohio R. R. Bonds ($5 000) carried as Current Funds		15 000.00	
			$15 683.76
Less checks drawn but not paid against cost of Proceedings			12 000.00
			$3 683.76

MISCELLANEOUS FUNDS

In addition to the regular Society funds the Secretary-Treasurer has on hand the following funds, partly invested as shown:

Committee A-1 on Steel	$65.04	
Committee A-3 on Cast Iron	1 415.00	
Committee A-5 on Corrosion of Iron and Steel	7 174.81	
Committee B-3 on Corrosion of Non-Ferrous Metals	6 108.65	
Committee C-1 on Cement	837.58	
Committee C-1 Cement Reference Laboratory	579.17	
Committee C-9 on Concrete and Concrete Aggregates	648.22	
Committee C-10 on Hollow Masonry Building Units	227.89	
Committee D-1 on Preservative Coatings	29.97	
Committee D-14 on Screen Wire Cloth	61.45	
Committee D-18 on Natural Building Stones	231.12	
Joint Committee on Investigation of Phosphorus and Sulfur in Steel	106.12	
A.S.A. Sectional Committee on Cast-Iron Pipe	310.20	
Total Committee Funds		$17 795 22

DUDLEY MEDAL AND MARBURG LECTURE FUND

Balance, January 1, 1929:		
Investments	$6 977.50	
Cash on hand	640.83	
		7 618.33
Receipts		
Interest on Deposits and Investments	$401.97	
Contribution	3.00	
		404.97
		$8 023.30
Disbursements		
Cost of 1929 Medal	$105.00	
Honorarium, 1929 Lecturer	200.00	
Engrossing 1929 Lecture Certificate	3.25	
		308.25
Balance December 31, 1929:		
Investments	$6 977.50	
Cash on hand	737.55	
		$7 715.05

INVESTMENTS

Society Funds

General:

$17 400	U. S. Liberty Bonds, 4th 4¼'s due 1938	$16 936.58
2 000	Michigan Central Equipment Bonds, 6's due 1932	2 085.96
1 000	Baltimore & Ohio R. R. Refunding & General Bonds, 6's due 1995	1 082.00
14 500	Baltimore & Ohio R. R. 20 year Convertible Bonds, 4½'s due 1933	14 606.55
	Carried forward	$34 711.09

	General (*Continued*):		
	Brought forward	$34 711.09	
2 000	Penna. R. R. Bonds Seconds, 5's due 1964	2 000.00	
3 000	Am. Tel. & Tel. Co. S. F. Deb. Bonds, 5's due 1960.	3 159.75	
6 000	Edison Elec. Illum. Co. of Boston, 4½ Notes due 1930	5 955.00	
500	Consolidated Gas Co. of N. Y. Bonds, 20 year 5½'s due 1945	531.00	
			$46 356.84
	A.S.T.M. Research Fund:		
$3 000	Baltimore and Ohio R. R. Refunding & General Bonds, 6's due 1995	$3 246.00	
1 500	Baltimore & Ohio R. R. 20 year Convertible Bonds, 4½'s due 1933	1 511.25	
1 500	Consolidated Gas Co. of N. Y. Bonds, 20 year 5½'s due 1945	1 593.00	
2 000	1st Mortgage Real Estate 6% Bonds on 1315–17 Spruce St	2 000.00	
			8 350.25
$8 000			
			$54 707.09
$54 400			

DUDLEY MEDAL AND MARBURG LECTURE FUND

$6 500	Baltimore & Ohio R. R. Refunding and General Bonds, 6's due 1995		6 977.50

COMMITTEE FUNDS

$7 100	U. S. Liberty Bonds, 4th 4¼'s due 1938:		
	Committee A-5	$6 731.36	
	Committee C-1	509.53	
			7 240.89
$68 000			$68 925.48

FINANCIAL CONDITION AT CLOSE OF FISCAL YEARS 1925–1929, INCLUSIVE.

Fiscal Year	Assets				Liabilities			
	Current Funds	Investments	Accounts Receivable	Furniture and Fixtures	Accounts Payable	Reserve for Book of Standards and Index to Proceedings	Special Funds	Surplus
1925	$5 041.21	$24 023.60	$3 946.20	$3 808.45	$1 036.92	$4 368.37	$1 805.20[b]	$29 608.77
1926	6 810.58	33 196.26	4 905.90	3 753.09	1 249.01	11 121.16	1 805.20[b]	34 490.46
1927	1 594.65	28 403.10	7 461.93	5 023.49	1 919.49	....	5 051.20	35 512.48
1928	978.56	44 752.09	6 831.10	5 327.09	972.04	6 057.80[a]	10 354.30	40 504.70
1929	3 683.76	54 707.09	6 226.93	5 896.31	1 913.27	12 012.80[a]	19 438.05	37 149.97

[a] Book of Standards Reserve only.
[b] Life Membership Fund only.

sheet, statement of receipts and disbursements, statement of miscellaneous funds held for committees, the Dudley Medal and Marburg Lecture Fund, and investments.

As will be seen from the balance sheet, the surplus at the close of the fiscal year was $37,149.97. In addition the life membership fund comprised $3005.30, and there was invested from 1929 income the sum of $5955 towards the cost of the *1930 Book of Standards*. The A.S.T.M. Research Fund was increased by $2000, the fund now comprising $8387.85. The Headquarters Fund, created to meet expenses incident to possible removal of the Society's headquarters, amounted to $5030; the Publications Fund, to meet cost of special or extraordinary publications, comprised $3015. A comparison of the financial condition of the Society at the close of the past five fiscal years is given in detail at the end of the auditor's report.

The report also lists the funds held for the account of committees and joint committees of the Society (totaling $17,795.22), and gives also a statement of the Dudley Medal and Marburg Lecture Fund, which shows a balance of $7715.05. Investments of Society and other funds are listed.

As will be seen from the financial report, there was a favorable balance between receipts and disbursements for the year of approximately $2700. At its meeting in January, 1930, when the finances of the fiscal year 1929 were reviewed, the Executive Committee assigned $1000 of this amount to the Publications Fund, to meet the expense of printing the papers for the Detroit Regional Meeting, and put the balance into a 1929 surplus fund as a reserve for contingencies.

In the foregoing financial statement no account has been taken of the assets of the Society in the form of publications in stock. The inventory on June 1, 1930, may be summarized approximately as follows:

		NUMBER OF COPIES
Proceedings		5 500
Index to Proceedings	Vols. I–XII, incl	510
	Vols. XIII–XX, incl	675
	Vols. 21–25, incl	655
Book of A.S.T.M. Standards	Part I, Metals	...
	Part II, Non-Metals	50
Reprints of 390 Standards	(Approximate)	25 000
Special reprints for general sale	(Approximate)	5 000

1930 Finances.—The Society's activities for the current fiscal year have been based on a budget that anticipates an income, exclusive of investments matured or sold, of $132,000, of which $89,250 are estimated from dues and entrance fees, $31,800 from sales of publications (including the triennial charge of $2 to members desiring both parts of the Book of Standards), and $11,950 from a number of miscellaneous items, including advertising in the *A.S.T.M. Bulletin* and in the Index to Standards and Tentative Standards, registration fee at annual meeting and interest on deposits and investments. In addition the funds set aside in 1928 and 1929 towards the cost of the *1930 Book of Standards* amount to approximately $12,000 and will be used this year; so that the total receipts for the year will be approximately $144,000.

Substantially the same policies have been applied this year as in previous years in making up the budget of disbursements. Provision has been made for a particularly heavy publication year, including as it does the triennial edition of the Book of Standards, which is steadily growing in size and is estimated will cost $23,500. The sum of $27,000 has been appropriated for the current *Proceedings;* and other items of publication expenses, including the *Year Book*, *Book of Tentative Standards*, Index to Standards and Tentative Standards, Selected Standards for Students, preprints, *A.S.T.M. Bulletin* and miscellaneous and special reprints, bring the total estimated disbursements for publications to $76,250. Usual provisions have been made for current expenses, including salaries, general office, standing committee and annual meeting expenses, headquarters maintenance, etc. One-half of the entrance fees (approximately $1800) will be added to the A.S.T.M. Research Fund.

Publicity of Society Activities:

Increasing attention has been given by the Executive Committee and the Society staff to adequate and dignified publicity of the activities of the Society as they develop throughout the year as well as on such occasions as the annual meeting and the group committee meetings. For a number of years the accounts of Society activities in the *A.S.T.M. Bulletin* have partly served the purpose of providing news of committee activities for use in the technical and trade journals. Such news is an excellent means of acquainting those outside of the Society with the nature of its activities and is interesting material for publication in journals. During the year this work has been extended by securing periodic statements from various committees of the Society respecting items of particular interest about their work, which are then released direct to the journals for publication. The committees have cooperated wholeheartedly with the staff in this work and the statements are used by the journals to a gratifying extent. For the past several years two member companies of the

Society have assigned a member of their staff trained in publicity work to take charge of general newspaper publicity of the annual meeting, and a similar arrangement was made with another member company for publicity in connection with the Detroit Regional Meeting. Publicity of these meetings in the technical journals is handled by the staff, which is now well organized for this purpose. An increase in the clerical staff during the year has made it possible to give some additional time to this work. The Executive Committee has also considered that the printing of the Detroit Regional Meeting papers and the publication of Selected A.S.T.M. Standards for Students are in themselves valuable aids in promoting knowledge of the Society's activities.

The Executive Committee has considered this whole subject to be of sufficient importance to warrant the appointment of a committee within the Executive Committee which will be responsible for the development of publicity activities along suitable lines.

Society Headquarters:

The five-year lease upon the quarters now occupied by the Society in the building of the Engineers' Club of Philadelphia expired at the close of 1929. The lease has been renewed at a slightly increased rental ($3000 annually) for a further two years with an option of extending the lease at the same rental for an additional one or two years.

The Engineers' Club has decided to remain at its present location and has completed alterations to the building which have greatly improved its attractiveness and usefulness as a clubhouse, and have provided a larger auditorium and several committee rooms. Unfortunately, these alterations were not of a nature that made it possible to provide adequate space for expansion of the Society's rooms. By slight alterations to the rooms, which involved giving up a room reserved principally for committee meetings, it has been possible to make more effective use of the space available; but it appears to be only a question of time, at the present rate of growth of the work, when consideration will have to be given to the procuring of more adequate Society rooms. Studies are being made of several possibilities for the establishment of Society headquarters in the event that it may prove necessary to make some change.

Meetings:

As the members have already been advised through the *A.S.T.M. Bulletin*, it has been decided to hold the annual meeting in 1931 in Chicago, the Stevens Hotel having been selected as headquarters.

It had been planned to hold the meeting this year in Chicago, but conflict of meeting dates prevented. Experience in arranging date and place of meetings has led the Executive Committee to adopt the policy of determining the time and place of annual meetings from a year and a half to two years in advance.

A Regional Meeting was held in Detroit on Wednesday, March 19, 1930—the first to have been sponsored by the Society. The meeting was held under the auspices of the Detroit members of the Society acting through the Detroit District Committee. From the technical side the meeting was devoted to a splendid Symposium on Developments in Automotive Materials, held in a morning and an afternoon session, in which over 300 members and guests participated. In the evening there was an informal dinner, which over 700 persons attended. The Detroit committee invited, both to the sessions and to the dinner, executives and technical men associated with the automotive and related industries in Detroit and vicinity. These invitations included the membership of the Detroit sections of the Society of Automotive Engineers, American Society for Steel Treating and the National Association of Purchasing Agents. In this way the committee has sought to interest many industrial firms in the region of Detroit that should be participating in one or more lines of A.S.T.M. work as members of the Society.

The Executive Committee has looked upon this regional meeting as marking a development in Society affairs of a significance far beyond the immediate purpose in mind. The Detroit members have taken the lead in bringing the work of the Society prominently before their industrial community and have furthered the spirit of cooperation with the automotive industry in the study of materials. Beyond this immediate purpose, there lies in the idea of regional meetings the thought of bringing the meaning of A.S.T.M. research and standardization in engineering materials more clearly to the attention of the industries of the country, by the personal contact that local meetings of this kind afford, and of extending the influence and membership of the Society among these industries. Such meetings will also develop a greater personal interest in Society affairs on the part of members in the various localities. The Executive Committee therefore will lend encouragement to groups of our members in other localities who might wish to carry out this idea in their own communities.

The Group Committee Meeting this spring, which it was found convenient to hold in conjunction with the Detroit Regional Meeting, was highly successful in every way. Not only in attendance, which was 475, but in the interest in the meetings and in the work accomplished by the committees, the Detroit meeting set a high standard for occasions of this kind and clearly showed the advantage of combining regional and committee meetings where practicable.

Relations with Pacific Coast Members:

The development of relationship with the members of the Society on the Pacific Coast has progressed steadily during the past year through the activities of the three district committees organized a year ago, announcement of the personnel having been made in the *A.S.T.M. Bulletin* for July, 1929. These committees comprise the three districts of Southern California, Northern California and Seattle. In the report of the Executive Committee a year ago there was published a number of recommendations and suggestions that were under consideration at that time. Several of these have been carried out, including the assignment of membership extension work to the several district committees and the appointment from each district of a "correspondent member" of the Committee on Papers and Publications primarily to stimulate the presentation of technical papers and discussions by the Pacific Coast members at annual meetings. (Partly as a result of this closer contact with the papers and publications work there are on the program of this annual meeting papers by five Pacific Coast members.) The district committees have been invited to review all phases of the committee work of the Society that are of interest to them and to make suggestions for the appointment to standing committees of members qualified to render useful service on these committees. (The decision to organize a standing committee on Mortars for Unit Masonry mentioned earlier in this report was a direct outgrowth of a suggestion by the Southern California District Committee that this subject be studied in the Society.) Consideration is being given to a plan of group representation in the activities of certain committees dealing with materials of particular interest on the Pacific Coast. It is probable that meetings of members of the Society in each of these districts will be held at about the time of the annual meeting, at which opportunity may be afforded for discussion of reports and papers on the program of the annual meeting.

Discussions with these district committees during the past year have emphasized the importance of developing a closer touch between the Pacific Coast members and the committee work of the Society. Particular attention will be given to this matter during the coming year.

Edgar Marburg Lecture for 1930:

Upon the recommendation of the Edgar Marburg Lecture Committee, consisting of G. W. Thompson, chairman, H. C. Knerr and F. R. McMillan, the Executive Committee has invited Dr. C. E. K. Mees, Director of Research and Development of the Eastman Kodak Co., to deliver the fifth Edgar Marburg Lecture at this annual meeting. Doctor Mees will speak on "Color and Its Measurement."

Award of the Charles B. Dudley Medal for 1930:

Upon the unanimous recommendation of the Committee on Medal Award, consisting of H. S. Vassar, chairman, H. M. Boylston and H. H. Quimby, the Executive Committee has awarded the Charles B. Dudley Medal to J. R. Townsend, Bell Telephone Laboratories, W. A. Straw, Western Electric Co., and C. H. Davis, American Brass Co., joint authors of a paper on "Physical Properties and Methods of Test for Some Sheet Non-Ferrous Metals" presented at the annual meeting of the Society a year ago.

Use of Test Data in Advertising:

In recent months several instances of misuse, in advertising, of data published by the Society have come to the attention of the Executive Committee. The Executive Committee has adopted the following statement of policy, which has already been announced to the members in the *A.S.T.M. Bulletin* and has been brought to the attention of firms whose use of Society data in their advertising has not been entirely satisfactory for one reason or another:

> RESOLVED, that data or statements quoted from Society reports for advertising purposes must be properly acknowledged and must be clearly identified as such and set apart from any interpretations or comments on them that are made by the advertiser. It is preferable that such data or statements shall be quoted in full. When considered necessary to abstract portions of data or statements, such abstracting must be satisfactory to the responsible committee of the Society and be sufficiently complete that it will not state or imply conclusions other than those stated in the official Society reports.

Policy on Approval of Apparatus by Society:

The Executive Committee has formulated certain policies to guide the Society and its committees in matters relating to the approval and use of testing apparatus conforming to A.S.T.M. standards. At various times the Society has been requested to give its formal approval to specific apparatus as conforming to the requirements of the Society for such apparatus. In the opinion of the Executive Committee it is not desirable that the Society should exercise such a function. At the same time there are often occasions where, through its appropriate committees, the Society might well examine or advise on apparatus, and the Society also desires to encourage in every way the development and marketing of testing apparatus that conforms to A.S.T.M. standards.

Accordingly the following policies were adopted after consultation with a number of leading apparatus manufacturers and dealers of testing apparatus:

1. The Society in general will not formally approve or certify any specific testing apparatus as conforming to A.S.T.M. standards or tentative standards for that type of apparatus.
2. The Society will welcome inquiries or information about testing apparatus intended to conform to A.S.T.M. requirements for such types of apparatus and will, through the appropriate committees of the Society, point out significant departures, if any, from the Society's requirements. Where no such departures are found, it will be suggested that the manufacturer place his own guarantee on the apparatus that it meets the A.S.T.M. requirements for that type of apparatus.
3. It is suggested that purchasers of testing apparatus secure a guarantee from the manufacturer or dealer that apparatus purchased for use in making tests in accordance with A.S.T.M. requirements, either standard or tentative, conforms with the specified requirements for such apparatus; and that instances of failure of apparatus to conform with A.S.T.M. requirements, when advertised or marketed as meeting such requirements, be reported to the Society.

These policies were announced to the members in the *A.S.T.M. Bulletin* for December, 1929, and by direct communication to the officers of all standing committees. As an outcome of discussion of these policies with a number of the manufacturers and dealers of testing apparatus, the Scientific Apparatus Makers of America, representative of practically all leading manufacturers of testing apparatus, proposed that the association and the Society cooperate in some suitable way in the development by the Society of specifications for testing apparatus. The association expressed its willingness to review all proposals for specifications for new apparatus or modification of specifications for existing apparatus, and to transmit to the Society any suggestions respecting the specifications that they might have to make as manufacturers of apparatus. The Executive Committee has accepted this offer of cooperation and is recommending that the standing committees through appropriate means secure the advice of the association in the determination of requirements for their testing apparatus, especially with respect to requirements of manufacture and tolerances. Arrangements for furthering this cooperative work are being discussed with the standing committees. For the present the plan is being put into effect by submitting to the association copies of all committee reports for the present annual meeting with the suggestion that criticisms and comments on recommendations affecting testing apparatus be made by the time of the annual meeting if possible.

American Standards Association:

Much of the detail of administrative work in connection with the Society's participation in the activities of the American Standards Association has been delegated by the Executive Committee to Committee E-10 on Standards. The present report is accordingly limited to a brief statement of certain administrative matters and announcement of important new developments.

The work of the American Standards Association has been developed along satisfactory lines under the reorganization effected in 1928, in which the administrative and financial responsibility for the work was concentrated in a Board of Directors composed of twelve industrial executives, leaving the technical work of approving standards in the hands of the "Standards Council" composed of representatives of the member bodies of the A.S.A. Through the efforts of the Board of Directors materially greater financial support of the work of the association is now assured, and it has been possible to enlarge the technical staff in such a way that the work of considering and approving American Standards and the stimulation of standardization work on a national scale should be greatly expedited.

The Executive Committee has placed in the hands of Committee E-10 general supervision of the submission of A.S.T.M. standards to the American Standards Association for approval as American Standard, with the request that this work be expedited as much as conditions will permit. It is desired to take advantage of the so-called "proprietary sponsorship plan" whereby standards may be offered for approval and subsequent revision within the procedure set up by the sponsor body, on the condition that it can be shown that the standard is acceptable to the various groups concerned with it. Considerable progress in this work has been made during the past year.

During the year the Society has organized as sponsor two sectional committees to function under A.S.A. procedure. The Sectional Committee on Specifications for Plastering was organized on February 24 under the joint sponsorship of the American Institute of Architects and the A.S.T.M., as the outgrowth of discussions that have taken place during recent years on the general subject of plastering specifications. The Society's Committees C-7 on Lime and C-11 on Gypsum have been especially interested in this subject and have made suggestions from time to time looking towards initiation of work in this field. The work covers the development of specifications for interior cement, lime and gypsum plastering and for exterior plastering. The personnel of the committee was announced in the *A.S.T.M. Bulletin* for March, 1930, although additions will be necessary to provide further representation of those interested in exterior plastering (stucco). The Society is represented in this work through six members appointed as follows: E. D. Boyer and W. B. Newberry from Committee C-1 on Cement, J. W. McBurney from Committee C-3 on Brick, J. A. Murray from Committee C-7 on Lime, F. E. Giesecke from Committee C-9 on Concrete and Concrete Aggregates and H. J. Schweim from Committee C-11 on Gypsum; and through the appointment of the Assistant Secretary of the Society as a member-at-large. The work of this committee should be of the utmost importance to the architectural profession and to the building owner as well as to contractors and the plastering trades.

The Sectional Committee on Fuel Oils was organized under the Society's sponsorship in Detroit on March 19. In essence it represents a merging of specification work on the subject planned by Committee D-2 on Petroleum Products and Lubricants with similar work on Diesel fuel oils developed in the American Society of Mechanical Engineers, together with specifications for domestic and industrial fuel oils developed by the American Oil Burner Association, the Division of Trade Standards of the Department of Commerce, and the A.S.T.M. The committee has been organized along broadly representative lines and contains formal representation of every group known to the Society to be interested in such specifications. So far as Society procedure is concerned, the committee will also function as the Technical Committee on Fuel Oils of Committee D-2, although the work will be carried on strictly in accordance with the established A.S.A. procedure. The Society has designated the following as its representatives on the sectional committee: J. T-B. Bowles, T. G. Delbridge, Harold Farmer, A. E. Flowers, H. C. Loudenbeck and J. B. Rather.

F. M. Farmer has been re-appointed as a representative of the Society on the Standards Council for a term of three years. H. L. Curtis and W. J. Shackelton have been designated as the Society's representatives on the Sectional Committee on Definitions of Technical Terms Used in Electrical Engineering. The Society is represented on the Sectional Committee on Stock Sizes, Shapes and Lengths for Hot and Cold-Finished Iron and Steel Bars by J. J. Shuman, with the Assistant Secretary as alternate.

International Relations:

International Federation of National Standardizing Associations (I.S.A.).—American participation in the activities of the International Federation of National Standardizing Associations (referred to hereafter as the I.S.A.) through formal membership therein of the American Standards Association is an important, forward-looking step taken last fall by the Board of Directors of the American Standards Association. The Society's position respecting international standardization of tests and specifications for materials, which has been defined in previous reports of the Executive Committee, was re-affirmed by formal resolution and transmitted to the A.S.A. in connection with the discussions that preceded the decision to join the I.S.A. The resolution follows:

> RESOLVED, that inasmuch as the A.S.T.M. is concerned in the standardization of engineering materials, we recommend to the Board of Directors of the A.S.A. the following actions:
>
> 1. That the A.S.A. join with the I.S.A. for certain definite purposes, to wit:
>
> (*a*) The discussion of national standard specifications for engineering materials for the purpose of bringing out the points of agreement or difference and the reasons therefor;
>
> (*b*) The discussion of methods of test and nomenclature of engineering materials for the purpose of bringing about the acceptance of similar methods and nomenclature by the various national standardizing bodies.
>
> 2. That the A.S.A. declare it believes it will be inexpedient for many years to come for any international body to adopt or promulgate international standard specifications for engineering materials.

The Executive Committee further emphasized the importance of developing and strengthening the *national* standardization program, as a prerequisite to adequate American participation in an international standardization movement. The establishment of a procedure in the A.S.A. for handling international projects on tests and specifications for materials through the A.S.T.M. as a sponsor body is also an important feature of our participation in this movement, and is now being discussed with the officers of the A.S.A.

A number of such international projects in the field of materials have been proposed in the I.S.A. and in accordance with I.S.A. procedure sent to the various national standardizing associations for comment. The A.S.A. has requested the views of the A.S.T.M., which have been expressed substantially as follows:

In answer to a proposal by the Russian national standardizing body that international standards for petroleum products be considered by the I.S.A., the opinion was expressed that no attempt should be made to prepare international standard specifications for petroleum products until internationally accepted methods of testing have been agreed upon, and that progress in the development of American standard methods of testing petroleum products under the procedure of the A.S.A. would justify American participation in discussion of such methods of testing for the purpose, as stated in the resolution above quoted, of bringing about acceptance of similar methods by the various national standardizing bodies. It has recently been suggested to the officers of the A.S.A. that the Society as sponsor for American standard methods of testing petroleum products is prepared to take a leading part in such international discussions if it is decided to make this subject an I.S.A. project.

Proposals for international standardization in methods of sampling and analysis of coal have been advanced. Here again the Society is sponsor for the American standard methods that have been developed, and the Executive Committee has expressed willingness to participate actively in international consideration of such methods. The subject of classification and nomenclature of coal is also of international interest, and the A.S.T.M. as sponsor for the A.S.A. Sectional Committee on Classification of Coal is prepared to participate through the sectional committee in an I.S.A. project on this subject.

Other suggested I.S.A. projects in the materials field have related to zinc and zinc ores, cast iron and cast steel, boiler plate, iron and steel pipe, rivets, and testing sieves and sieve analyses. With respect to each of these subjects, the A.S.A. has been informed of all the A.S.T.M. has accomplished in the respective fields and the assurance has been given that the Society is ready to cooperate with the A.S.A. respecting any proposals for international consideration of these subjects that may be advanced, and to aid in developing American participation in so far as the industries concerned may be prepared to go.

Cooperation with Germans on Testing of Petroleum Products.—In response to a proposal from the Committee on Lubricants of the German Society for Testing Materials for cooperative work between that Society and the A.S.T.M. in the field of testing lubricants, arrangements have been completed for formal cooperation between the committees of the two societies dealing with petroleum products. The German Society for Testing Materials has appointed Dr. Jur Hilliger as its representative on the Society's Committee D-2 on Petroleum Products and Lubricants. Similarly, the secretary of Committee D-2, R. P. Anderson, has been appointed by the Executive Committee as a member of the Committee on Lubricants of the German Society. A formal exchange of minutes, reports and papers has been instituted. Somewhat similar cooperative relations have existed for some years between the Society and the Institution of Petroleum Technologists of Great Britain, and the extension of such relationships to the German Society should be helpful in promoting uniformity in the methods of testing petroleum products in various countries, touched upon in the preceding section of this report.

International Association of Road Congresses.—The Society has accepted an invitation to participate formally in the Sixth Congress of the Permanent International Association of Road Congresses, which is to convene in Washington this fall. The principal interest of the Society in the Congress is, of course, with respect to methods of test and specifications for road and paving materials and in nomenclature and definitions relating thereto. In the past year Committees D-4 on Road and Paving Materials, D-2 on Petroleum Products and Lubricants and D-8 on Bituminous Waterproofing and Roofing Materials have given further consideration to the definitions of certain terms relating to bituminous materials that are under consideration in a committee of the International Association of Road Congresses, to which reference was made in the report of the Executive Committee a year ago. Substantial agreement having been reached between the three committees on definitions of these terms, a report thereon has been forwarded to the American member of the Road Congress Committee for consideration of that committee.

New International Association for Testing Materials.—During the year the Society has received very little information about the activities of the New International Association for Testing Materials, which it is presumed, however, are directed principally to the plans for the next international congress to be held in Zurich in 1931. W. H. Fulweiler, the Society's representative on the Permanent Committee of the N.I.A.T.M., as reported a year ago, arranged for the preparation of eighteen preliminary reports by especially qualified members of the Society, upon topics that the Society would be interested to see included in the program of the next congress, and these reports were forwarded to the officers of the International Association and to the chairmen of the four sections under which its activities are being developed, namely, A, Metals; B, Non-Metallic Inorganic Materials; C, Organic Materials; and D, Questions of General Importance. Consideration will be given by the Executive Committee within the next few months to the nature and extent of formal Society participation in this congress.

On June 1, 1930, there were 265 members of the Society who were members of the International Association, 47 being company and 218 individual members.

Fiftieth Anniversary Meeting, American Society of Mechanical Engineers:

By resolution of the Executive Committee, greetings were conveyed to the American Society of Mechanical Engineers on the occasion of its recent Fiftieth Anniversary Celebration held in New York and Washington, April 5 to 9. The greetings were engrossed and presented formally by the Society's official delegates to the anniversary celebration, President T. D. Lynch and Past-President A. A. Stevenson. The occasion was an outstanding one in the history of American engineering and the Society joins with all who participated in this meeting in extending felicitations and congratulations to the American Society of Mechanical Engineers.

Miscellaneous Cooperative Work:

Much cooperative work with other organizations in addition to that previously recounted in this report is carried on each year on an established and practically routine basis through joint committees, representation of other Societies on A.S.T.M. committees and Society representation upon committees of other organizations. Mention of many of these projects, both in the fields of research and of standardization, will be found in the annual reports of Committees E-9 on Correlation of Research and E-10 on Standards. A few such examples of cooperative work that have engaged the attention of the Executive Committee during the past year are commented upon briefly below:

The Joint Committee on Concrete and Reinforced Concrete, the activities of which are sponsored by the American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering Association, American Concrete Institute and Portland Cement Association, presented in 1924 a report of the results of its work over the four years since its organization in 1920 The Joint Committee has not been active since 1924, believing that opportunity should be given for a thorough trial of the Specifications for Concrete and Reinforced Concrete that the committee had prepared. During these six years much progress has been made in this field and it has been decided to reconvene the Joint Committee for further work on this subject. In this period there have been a number of changes of personnel through death and resignation and the five sponsor bodies are reviewing the appointment of representatives upon the reorganized committee. In the case of the Society, the death of Richard L. Humphrey, who was chairman of the Joint Committee, and the resignation of H. H. Quimby, has left two vacancies, which have been filled by the appointment of Cloyd M. Chapman and P. H. Bates. Mr. Chapman has been designated as chairman of the A.S.T.M. representation on the Joint Committee, which is now as follows: P. H. Bates, Cloyd M. Chapman, A. T. Goldbeck, E. E. Hughes and L. S. Moisseiff.

The Society is cooperating with a number of other organizations in a project known as Alloys of Iron Research, sponsored by the Engineering Societies Research Board and the American Institute of Mining and Metallurgical Engineers. The purposes of this project are, briefly, to make available all reliable information in the great mass of literature in many languages; to publish the information; to correct and eliminate errors in existing data on iron and its alloys; and to increase the precision of data no longer adequate to the refinements of present-day industrial processes. The project is receiving adequate financial support by industry. The Society's representative on the research committee is Jerome Strauss.

The Society has accepted an invitation from the Merchants Association of New York to act in an advisory capacity to the association in the development of the revised building code of the City of New York. This code is so extensive as to cover a great many materials for which the Society has written specifications and methods of test and it is felt the Society can be of service in advising on the applicability of its standards for reference in the code. R. E. Hess, Assistant Secretary of the Society, is serving on the Advisory Committee.

Respectfully submitted on behalf of the Executive Committee,

T. D. LYNCH,
President.

C. L. WARWICK,
Secretary-Treasurer.

REPORT OF COMMITTEE A-1
ON
STEEL

During the past year Committee A-1 held two meetings, one on January 17, and the second on March 21, 1930. A third meeting will be held prior to the presentation of this report to the Society, at which the report will be reviewed and other matters considered.

The Advisory Committee has held three meetings at which matters concerning the general administrative affairs of the committee were considered.

The present membership of the committee is 192, of which 80 are classed as producers, 84 as consumers and 28 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards are presented first in summarized form together with an analysis of the letter ballot on each item.

They are then referred to, where necessary, in greater detail, being grouped for convenience in the order of the respective subcommittee directly responsible for them.

Proposed New Tentative Standards.—The committee recommends that the following proposed new tentative specifications be accepted for publication as tentative as appended hereto:[1]

Proposed Tentative Specifications for Austenitic Manganese Steel Castings;

Proposed Tentative Specifications for Open-Hearth Iron Plates of Flange Quality.

Proposed Revisions in Standards.—The committee recommends that revisions in the following standards, which are given in full in the Appendix to this report, be submitted to letter ballot of the Society. These revisions are divided into two groups, as follows:

Group A.—Revisions in the following standards which the committee recommends be referred to letter ballot of the Society immediately by the necessary nine-tenths vote of the annual meeting, for adoption as standard:

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[1] See pp. 969 and 965, respectively.—ED.

Standard Specifications for Commercial-Quality Hot-Rolled Bar Steels (A 107 – 27);

Standard Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 27);

Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A 78 – 27);

Standard Specifications for Steel Plates of Flange Quality for Forge Welding (A 89 – 27);

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27).

Group B.—Revisions in the following standards recommended for publication as tentative for one year before referring them to letter ballot of the Society for adoption:

Standard Specifications for Structural Steel for Ships (A 12 – 21);

Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 27).

Advancement of Tentative Standards to Standard.—The committee recommends that the following three tentative standards be advanced to standard, with revisions in the two specifications as given in detail in the Appendix:

Tentative Specifications for Steel Tie Plates (A 67 – 26 T), as revised;

Tentative Specifications for Iron and Steel Chain (A 56 – 28 T), as revised;

Tentative Methods of Sampling Rolled and Forged Steel Products for Check Analysis (A 33 – 28 T), without revision.

Advancement to Standard of Tentative Revisions of Standards.—The committee recommends that the tentative revisions, proposed in 1928 and 1929, in the following standards be adopted as standard:

Standard Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 27);

Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 14);

Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (A 18 – 28);

Standard Specifications for Welded and Seamless Steel Pipe (A 53 – 27);

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27).

Tentative Standards Continued as Tentative.—The committee recommends that the following tentative specifications be continued as tentative for another year without revision:

- Tentative Specifications for Carbon Steel Forgings for Locomotives (A 20 – 29 T);
- Tentative Specifications for Steel Track Spikes (A 65 – 26 T);
- Tentative Specifications for Electric Cast-Steel Stud-Link Anchor Chain (A 77 – 28 T);
- Tentative Specifications for Cold-Rolled Strip Steel (A 109 – 27 T);
- Tentative Specifications for Black and Hot-Dipped Zinc-Coated Welded and Seamless Steel Pipe for Ordinary Uses (A 120 – 28 T);
- Tentative Specifications for Marine Boiler Steel Plates (A 114 – 27 T);
- Tentative Specifications for Heat-Treated Carbon-Steel Helical Springs (A 125 – 29 T).

The above recommendations have been referred to letter ballot of the committee, which consists of 192 members; 56 ballots have been cast, 136 members having failed to return their ballot. The analysis of the vote of the committee is given in the following table:

Items	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE STANDARDS			
Specifications for Austenitic Manganese Steel Castings	33	1	22
Specifications for Open-Hearth Iron Plates of Flange Quality	40	1	15
II. PROPOSED REVISION OF STANDARDS			
Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 – 27), immediate adoption	41	1	14
Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 27), immediate adoption	34	1	21
Specifications for Steel Plates of Structural Quality for Forge Welding (A 78 – 27), immediate adoption	41	0	15
Specifications for Steel Plates of Flange Quality for Forge Welding (A 89 – 27), immediate adoption	41	0	15
Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27), immediate adoption	36	0	20
Specifications for Structural Steel for Ships (A 12 – 21)	37	0	19
Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 27)	40	0	16
III. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Specifications for Steel Tie Plates (A 67 – 26 T), as revised	34	3	19
Specifications for Iron and Steel Chain (A 56 – 28 T), as revised	37	1	18
Methods of Sampling Rolled and Forged Steel Products for Check Analysis (A 33 – 28 T)	41	0	15
IV. ADVANCEMENT TO STANDARD OF TENTATIVE REVISIONS OF STANDARDS			
Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 27)	38	0	18
Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 – 14)	38	3	15
Specifications for Carbon-Steel and Alloy-Steel Forgings (A 18 – 28)	39	0	17
Specifications for Welded and Seamless Steel Pipe (A 53 – 27)	34	0	22
Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27)	35	0	20

SUBCOMMITTEE ACTIVITIES

In the following the committee presents the foregoing recommendations, in detail where necessary, as well as other features of its work, grouped for convenience in the order of the respective subcommittees responsible for them.

Subcommittee I on Steel Rails and Accessories (E. F. Kenney, chairman).—This subcommittee is developing proposed specifications for intermediate manganese steel rails in cooperation with the American Railway Engineering Association. The committee is also cooperating with the A.R.E.A. in the consideration of the present Tentative Specifications for Soft Steel Track Spikes (A 65 – 26 T) and accordingly recommends that they be continued as tentative.

The subcommittee is proposing a revision in the branding clause, as given in the Appendix, of the Tentative Specifications for Steel Tie Plates (A 67 – 26 T), and recommends that the specifications be advanced to standard as revised.

The subcommittee also recommends that the tentative revision[1] of the Standard Specifications for Open-Hearth Carbon-Steel Rails (A 1 – 27) recommended last year be advanced to standard.

Subcommittee II on Structural Steel for Bridges, Buildings and Rolling Stock (A. W. Carpenter, chairman).—Subcommittee II has made an exhaustive inquiry into the advisability of changing the tensile requirements of present structural steel grades to a higher range. The present status, as reported by the subcommittee, was that the demand did not apparently warrant such a change at the present time. The committee is now working on the proposal of presenting new specifications for higher strength structural steel of the so-called medium grade for submission to the Society for publication as tentative.

The committee is also considering a revision in the tensile strength and other requirements for rivet steel in existing standard specifications under its jurisdiction.

Subcommittee III on Structural Steel for Ships (R. C. Davis, chairman).—Subcommittee III is recommending a tentative revision, as given in the Appendix, of the present Standard Specifications for Structural Steel for Ships (A 12 – 21) and is now actively working on a complete revision of these specifications and of the Standard Specifications for Rivet Steel for Ships (A 13 – 24), and expects to submit a combined specification covering these two specifications, for submission as a tentative standard to Committee E-10 on Standards during the ensuing year.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 853 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 807.

Subcommittee IV on Spring Steel and Steel Springs (H. W. Faus, chairman).—This subcommittee has recalculated the table of test loads for helical springs appearing in the appendix to the Standard Specifications for Helical Steel Springs for Railways (A 61 - 16), and accordingly recommends that the present table appearing in the standard specifications be replaced by the revised table reproduced as the accompanying Table I.[1]

Subcommittee V on Steel Reinforcement Bars (H. H. Morgan, chairman).—Subcommittee V is recommending the advancement to standard of the tentative revision[2] of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A 15 - 14), proposed in 1928, which involves the elimination of the present recommendation that the structural grade be used unless otherwise specified, an increase in the allowable tensile range with no decrease in the minimum ductility, and an increase in the phosphorus limits in acid steels.

Subcommittee VI on Steel Forgings and Billets (H. P. Tiemann, chairman).—This subcommittee is considering a revision of the Tentative Specifications for Carbon-Steel Forgings for Locomotives (A 20 - 29 T) and accordingly recommends that these specifications be continued as tentative for another year. The subcommittee is also proceeding to develop specifications for normalized and tempered high-tensile alloy-steel forgings and is considering the revision of the present Standard Specifications for Quenched-and-Tempered Alloy-Steel Axles, Shafts, and Other Forgings for Locomotives and Cars (A 63 - 27).

This subcommittee recommends that the tentative revision,[3] presented last year, of the Standard Specifications for Carbon-Steel and Alloy-Steel Forgings (A 18 - 28) be advanced to standard.

Subcommittee VIII on Steel Castings (P. E. McKinney, chairman).—This subcommittee is presenting for publication as tentative the Proposed Tentative Specifications for Austenitic Manganese Steel Castings, appended hereto.[4] These specifications were developed as the result of rather insistent demands for specifications for alloy steels which after consideration indicated that among the various alloy steels, austenitic manganese steel was the only type of material in cast form which had found a rather wide application and on which composition and production practice was more or less standardized and on which there appeared to be a rather strong demand for specifications.

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[1] This table now appears in the Standard Specifications for Helical Springs for Railways (A.S.T.M. Designation: A 61), see 1930 Book of A.S.T.M. Standards, Part I, p. 160.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 853 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 807.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 853 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 807.

[4] See p. 969.—ED.

This subcommittee is circularizing interested technical societies to determine the necessity for preparing specifications for alloy-steel castings.

Subcommittee IX on Steel Tubing and Pipe (H. H. Morgan, chairman).—Subcommittee IX reports progress in the development of complete specifications for fusion and resistance-welded pipe, hammer-welded pipe, lock-bar pipe, fabricated and riveted pipe of all kinds, as planned last year, and has appointed five sub-subcommittees dealing with the individual classes of material under such specifications.

This subcommittee recommends that the tentative revisions[1] recommended last year in the Standard Specifications for Welded and Seamless Steel Pipe (A 53 - 27) be advanced to standard.

This subcommittee is joining with Subcommittee I on Tubes and Pipe of Committee A-2 on Wrought Iron in recommending for immediate adoption a revision, given in the Appendix, of the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 27), and in recommending that the tentative revision[1] proposed last year be advanced to standard.

Subcommittee XI on Boiler Steel (E. J. Edwards, chairman).—As a result of a request by the Boiler Code Committee of the American Society of Mechanical Engineers for specifications covering open-hearth iron plates suitable for use in the construction of unfired pressure vessels, this subcommittee has developed Proposed Tentative Specifications for Open-Hearth Iron Plates of Flange Quality, appended hereto.[2] The subcommittee recommends that these specifications be published as tentative. The subcommittee is also considering the development of specifications for alloy-steel plate of firebox quality and also the revision of the Standard Specifications for Boiler Rivet Steel (A 31 - 24).

Subcommittee XII on Methods of Chemical Analysis (G. E. F. Lundell, chairman).—Subcommittee XII is working on proposed changes in the standard procedures for determining carbon, manganese, silicon and possibly sulfur and copper in high sulfur steels. New methods for determination of alumina and aluminum are being developed.

The subcommittee recommends that the Tentative Methods of Sampling Rolled and Forged Steel Products for Check Analysis (A 33 - 28 T) be advanced to standard.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 854 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 808.

[2] See p. 965.—ED.

Subcommittee XV on Commercial Bar Steels (J. J. Shuman, chairman).—Subcommittee XV in cooperation with the Iron and Steel Division of the Society of Automotive Engineers has agreed upon and is presenting for immediate adoption a revision, given in the Appendix, in the Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 – 27) and for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 27) involving an increase in the sulfur limits of bessemer screw stock in order to improve the machineability.

Subcommittee XVI on Cast Steel Chain (F. M. Waring, chairman).—This subcommittee is joining with Subcommittee V on Chain Iron and Iron Chain of Committee A-2 on Wrought Iron in recommending that the Tentative Specifications for Iron and Steel Chain (A 56 – 28 T) be revised, as indicated in the Appendix, and advanced to standard to supersede the present Standard Specifications for Iron and Steel Chain (A 56 – 24).

Subcommittee XXI on Steel for Welding (F. N. Speller, chairman).—Subcommittee XXI has gone carefully into the requirements of steel for fusion welding and has presented a formal statement that steel made under the following A.S.T.M. specifications can be welded satisfactorily by the usual fusion processes now in general use:

Standard Specifications for Structural Steel for Bridges (A 7 – 29);
Standard Specifications for Structural Steel for Buildings (A 9 – 29);
Standard Specifications for Structural Steel for Locomotives and Cars (A 113 – 29);
Standard Specifications for Structural Steel for Ships (A 12 – 21);
Standard Specifications for Boiler and Firebox Steel for Locomotives (A 30 – 24);
Standard Specifications for Boiler and Firebox Steel for Stationary Service (A 70 – 27);
Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A 78 – 27);
Standard Specifications for Steel Plates of Flange Quality for Forge Welding (A 89 – 27);
Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27);
Standard Specifications for Welded and Seamless Steel Pipe (with carbon restriction) (A 53 – 27);
Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (A 82 – 27);

Tentative Specifications for Black and Hot-Dipped Zinc-coated (Galvanized) Welded and Seamless Steel Pipe for Ordinary Uses (A 120 - 28 T).

This report is not presented as final and is being referred to the other subcommittees of Committee A-1, as well as other committees on ferrous metals for additions or changes to the above list of specifications. Comments and criticisms on the above statement will be welcomed by the subcommittee.

The subcommittee has voted to take no action at present on the development of specifications for electrodes (welding wire) in view of the work being done by the American Welding Society on this matter. The importance of electrode material, however, is fully recognized.

The subcommittee is recommending for immediate adoption a revision, given in the Appendix, of the Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A 78 - 27) and for Steel Plates of Flange Quality for Forge Welding (A 89 - 27) which will permit the use of silicon in excess of 0.05 per cent by mutual agreement between the manufacturer and the purchaser.

Subcommittee XXII on Valves, Fittings, Piping and Flanges for High-Temperature Service (L. W. Spring, chairman).—Subcommittee XXII is considering the physical properties of alloy-steel bolting in sizes larger than 2½ in. in diameter under the Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 - 27) to determine whether a higher alloy content is necessary to obtain the full strength in these larger sections.

The subcommittee is recommending a tentative revision, as given in the Appendix, in Specifications A 96 - 27 involving the location for selecting tension test specimens and the addition of a footnote to the title relative to sizes of bolting stock covered by the specifications.

Consideration is being given by the subcommittee to the development of specifications for materials to be used under pressures of 1500 lb. per sq. in. and at temperatures of 1000° F.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 192 members; 56 members have returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. B. YOUNG,
Chairman.

V. H. LAWRENCE,
Secretary.

EDITORIAL NOTE

The proposed Tentative Specifications for Austenitic Manganese Steel Castings and for Open-Hearth Iron Plates of Flange Quality were accepted for publication as tentative and appear on pages 969 and 965, respectively.

The proposed immediate revisions of the Standard Specifications for Commercial Quality Hot-Rolled Bar Steels; for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting; for Steel Plates of Structural Quality for Forge Welding; for Steel Plates of Flange Quality for Forge Welding; and for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes were approved at the annual meeting by a unanimous vote and were subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 140, 144, 122, 127, and 238, respectively.

The proposed revisions of the Standard Specifications for Structural Steel for Ships; and for Alloy-Steel Bolting Material for High-Temperature Service were accepted for publication as tentative and appear on pages 1269 and 1270, respectively.

The Tentative Specifications for Iron and Steel Chain, to supersede the present Standard Specifications for Iron and Steel Chain; the Specifications for Steel Tie Plates; and the Tentative Methods of Sampling Rolled and Forged Steel Products for Check Analysis were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 459, 63 and 315, respectively.

The tentative revisions of the Standard Specifications for Open-Hearth Carbon-Steel Rails; for Billet-Steel Concrete Reinforcement Bars; for Carbon-Steel and Alloy-Steel Forgings; for Welded and Seamless Steel Pipe; and for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 19, 131, 178, 245 and 238, respectively.

APPENDIX

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR STEEL

In this Appendix are given proposed revisions in certain standard and tentative specifications. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

PROPOSED REVISION OF STANDARDS

Group A. Recommended for Immediate Adoption

Standard Specifications for Commercial Quality Hot-Rolled Bar Steels (A 107 – 27)[1] *and Standard Specifications for Commercial Cold-Finished Bar Steels and Cold-Finished Shafting (A 108 – 27):*[1]

Table I.—Under the heading "Screw Steel Grades" change the limits for sulfur in the bessemer screw steel from the present requirements "0.075–0.15" to read "0.10–0.18."

Standard Specifications for Steel Plates of Structural Quality for Forge Welding (A 78 – 27)[2] *and Standard Specifications for Steel Plates of Flange Quality for Forge Welding (A 89 – 27):*[2]

Section 3.—Change Paragraph (*b*) from its present form: namely,

> (*b*) The composition of the steel should preferably be free from silicon, nickel or chromium. Where these elements are present the maximum quantity of any one shall not exceed 0.05 per cent.

to read as follows:

> (*b*) The steel should preferably be free from nickel and chromium. When these elements are present the maximum quantity of either one shall not exceed 0.05 per cent. Unless otherwise specified, the silicon shall not exceed 0.05 per cent.

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27)[3]*:*

Section 4 (b).—Change to read as follows by the addition of the italicized word and the omission of the words in brackets:

---

[1] 1927 Book of A.S.T.M. Standards, Part I, pp. 141–148.

[2] *Ibid.*, pp. 123–131.

[3] *Ibid.*, p. 242.

(b) If the analysis of [only one] *either* tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

Section 13.—Change to read as follows by the addition of the italicized word and the omission of those in brackets:

13. If the results of the physical tests of [only one tube] *either of the tubes, selected for physical test* [from any lot] do not conform to the requirements specified in Sections 6, 7 and 8, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

Section 16 (*a*).—There was a tentative revision of this section recommended last year.[1] It is now recommended that the expression in this revision which reads "shall not vary more than" be changed to read "shall not be more than." It is also recommended that this section be renumbered as Section 15 (*b*). With the inclusion of these recommendations this section would then be changed from its present form: namely,

16. (*a*) Finished tubes 4 in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 4 in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

to read as follows:

(*b*) The outside diameter of finished tubes shall not be more than $\frac{1}{64}$ in. over the size ordered. For finished tubes up to and including 4 in. in outside diameter, the outside diameter shall not be more than $\frac{1}{32}$ in. under the size ordered and for tubes over 4 in. in outside diameter, the outside diameter shall not be more than $\frac{3}{64}$ in. under the size ordered.

Reletter Paragraphs (*b*), (*c*), (*d*), (*e*) and (*f*) of Section 16 as Paragraphs (*c*), (*d*), (*e*), (*f*) and (*g*) of Section 15, and renumber the remaining sections accordingly.

Group B. Recommended for Publication as Tentative.

Standard Specifications for Structural Steel for Ships (*A 12 – 21*):[2]

Section 5.—Add the following elongation requirement to the table of requirements as to tensile properties appearing after Paragraph (*a*):

Elongation in 2 in., minimum, per cent........................ 22

Section 9.—Change Paragraph (*c*) from its present form: namely,

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 109 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 809.

[2] 1927 Book of A.S.T.M. Standards, Part I, p. 99.

to read as follows:

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*), and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Table II.—Add a note to Table II on Permissible Overweights of Plates Ordered to Thickness, to read as follows:

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

Standard Specifications for Alloy-Steel Bolting Material for High-Temperature Service (A 96 – 27):[1]

Footnote.—Add the following footnote to the title of these specifications.

These specifications cover bolting stock up to and including $2\frac{1}{2}$ in. in diameter.

Section 12.—Add an additional Paragraph (*c*) to read as follows:

(*c*) Specimens for tension tests shall be taken longitudinally. For sizes under $1\frac{1}{2}$ in. in diameter the full section shall be turned to conform to requirements specified in Paragraph (*a*). For sizes $1\frac{1}{2}$ in. and larger the specimen shall be taken half way between the center and surface.

PROPOSED REVISIONS OF TENTATIVE STANDARDS

Tentative Specifications for Steel Tie Plates (A 67 – 26 T):[2]

Section 13.—Change this section to read as follows by the addition of the italicized words:

13. The name or brand of the manufacturer, the section *of the tie plate* and the year of manufacture shall be rolled in raised letters and figures on the outside of the shoulder of the plates, and a portion of this marking shall appear on each finished tie plate.

Tentative Specifications for Iron and Steel Chain (A 56 – 28 T):[3]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

2. The material entering into the two classes of chain shall be as follows:

CRANE CHAIN.—[Wrought iron which] *Crane chain* shall be made from [all pig puddled] *wrought* iron[a] free from any admixture of iron scrap or steel.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought Iron Specifications (A.S.T.M. Designation: A 81 – 30) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag."

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 265.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 633 (1926); also 1929 of Book A.S.T.M. Tentative Standards, p. 23.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 697 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 42.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products of crane chain iron quality.

PROOF COIL.—[Wrought iron or open-hearth steel.] [The wrought iron] *Proof coil* may be made from *open-hearth steel or* all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

Section 4.—In the table change the requirements for phosphorus and sulfur in Steel Proof Coil to read as follows by the addition of the italicized figures and the omission of those in brackets:

	STEEL PROOF COIL
Phosphorus, maximum, per cent........................	[0.04] *0.05*
Sulfur, maximum, per cent...........................	[0.04] *0.05*

Section 5 (b).—Check analysis.— Change from its present form: namely,

(*b*) Samples for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which the drillings are taken, and the borings shall be taken through the bar from surface to surface.

to read as follows:

(*b*) Drilling for analysis shall be taken from the entire cross-section of the bar.

JOINT RESEARCH COMMITTEE
ON
EFFECT OF TEMPERATURE ON THE PROPERTIES OF METALS

PROGRESS REPORT TO THE SPONSOR SOCIETIES

The past year has been an active one for the committee and progress can be reported both as regards the committee's research program and the development of its organization. Four meetings were held, two in New York, one in Detroit, and one in Atlantic City.

Reorganization:

The committee was enlarged and reorganized to secure better representation and more effective cooperation of the various industries interested in the effect of temperature on the properties of metals. Four permanent committees were created within the joint committee to handle the major phases of its work and to provide, through various subcommittees, a flexible organization permitting expansion and contraction of activities as required:

Committee I on Organization and Membership
Committee II on Finances
Committee III on Technical Projects
Committee IV on Correlation of Technical Data

Subcommittees for specific projects will be organized as required. Organization of the different subcommittees, for example those of Committe III on Projects, is proceeding at a satisfactory rate.

The personnel of the committee was expanded and an "advisory and cooperating membership" established to provide contact and procure the advice and assistance of many of those men whose professional duties will not permit them to assume the full burden of membership on the joint committee.

Sessions Sponsored by the Committee:

The committee sponsored a technical session on the high-temperature properties of metals during the spring meeting of the

American Society of Mechanical Engineers in Detroit, June 9, 1930, at which the following three papers were read and discussed:

"Flow Characteristics of Special Fe-Ni-Cr-Alloys and Some Steels at Elevated Temperatures," H. J. French, W. Kahlbaum and A. A. Peterson.

"Flow Characteristics of Some Lead Cable Sheath at Temperatures Above Atmospheric," C. L. Clark and C. Upthegrove.

"An Apparatus for the Determination of Creep at Elevated Temperatures," A. E. White, C. L. Clark and L. Thomassen

Another paper on "Some Long-Time Tension Tests of Steels at Elevated Temperature," by J. J. Kanter and L. W. Spring, is being presented under committee auspices at the June, 1930, meeting of the American Society for Testing Materials, and appears as Appendix II to this report. Consideration is now being given to the practicability of sponsoring a second symposium on the effect of temperature on the properties of metals late in 1930 or during 1931 to take account of progress in the six years since the first symposium, which was held in Cleveland in 1924.

Bibliography:

Plans have now been made to issue yearly or bi-yearly additions to the bibliography on effect of temperature on the properties of metals which was prepared by the committee and published in 1928 in pamphlet form by the American Society of Mechanical Engineers. The first supplement covering the period 1927–1930 has been prepared and is being published by that society.

Through the courtesy of the metallurgical division of the U. S. Bureau of Standards a bibliography on the oxidation of metals at high temperatures is also submitted at this time to the sponsor societies and is being published by the American Society of Mechanical Engineers.

Test Code for High-Temperature Mechanical Tests:

Work has been continued in the test program designed to develop data upon which to base test codes for high-temperature tension tests and high-temperature creep tests. A further report relating to these matters has been prepared by subcommittees and is presented as Appendix I to this report.

Finance:

The committee has encountered difficulty during the year in securing a consistent flow of data in the research program. This has been due in part to personnel changes in the committee and in the cooperating laboratories and in part to the nature of some of the tests which require considerable time and special equipment. In most cases, the committee tests have had to be made on equipment needed in the solution of individual problems by the several cooperating laboratories.

With the proposed extensions to its program the committee should be in a position to avoid such conflicts and accordingly has laid plans to secure adequate financial support so that it may have the full-time services of both men and equipment for its work. Details of these plans will be reported upon at a later date.

Respectfully submitted on behalf of the joint committee,

H. J. FRENCH,
Chairman.

N. L. MOCHEL,
Secretary.

APPENDIX I

SECOND REPORT ON COMPARATIVE HIGH-TEMPERATURE TENSION TESTS OF METALS AT DIFFERENT LABORATORIES

INTRODUCTION

Since the publication of the first or preliminary report,[1] additional data have been submitted to the Subcommittee on Analysis and Correlation of Short-Time Tension Tests and form the basis of the second report.

The subject matter of this report relates, first, to new data on a high-chromium (stain-resisting) steel, and, second, to a further discussion of some of the results which were included in the preliminary report. It will be recalled that there were some notable differences in the results obtained at different laboratories on the same steels and that insufficient information was available to explain the origin of the variations encountered or to permit recommendations to promote closer agreement. During the past year, following the presentation of the first report, members of the subcommittee have developed additional information through correspondence with cooperators, and it is this material which is considered in some detail.

COOPERATORS

The tests discussed were made in the laboratories of thirteen of the cooperators as follows:

The Babcock & Wilcox Co., Bayonne, N. J.
Bureau of Standards, Washington, D. C.
Chapman Valve Manufacturing Co., Indian Orchard, Mass.
Crane Co., Chicago, Ill.
The Lunkenheimer Co., Cincinnati, Ohio.
Scovill Manufacturing Co., Waterbury, Conn.
Union Carbide and Carbon Co., Research Labs., Inc., Long Island, N. Y.
University of Illinois, Urbana, Ill.
University of Michigan, Ann Arbor, Mich.
Walworth Co., Boston, Mass.
Watertown Arsenal, Watertown, Mass.
Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.
Wright Field, Material Division, Air Corps, U. S. Army, Dayton, Ohio.

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[1] Preliminary Report on Comparative High-Temperature Tension Tests on a Carbon Steel and on a Chromium-Molybdenum Steel at Different Laboratories, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 143 (1927).

The subcommittee has not yet received authorization to credit the results to the respective laboratories, and therefore the sources of the described data are represented by code numbers.

STEELS TESTED

The steels used in the tests discussed in this report were a carbon steel, K1, a high-chromium stain-resisting steel, K2, and a chromium-molybdenum steel, K3. Their chemical compositions and treatments prior to test are given in Table I.

NEW TESTS ON THE HIGH-CHROMIUM STEEL, K2

Figures 1 and 2 contain a graphical summary of the results obtained at three different laboratories on the high-chromium (stain-resisting) steel K2, and it will be noted that good agreement has been obtained in all properties except the proportional limit. Maximum variations from average values of tensile strength and proportional limit at the different temperatures are summarized in Fig. 3. This chart shows both the actual and percentage deviations from the average values of all of the reported tests.

TABLE I.—CHEMICAL COMPOSITION AND OTHER DETAILS OF THE STEELS USED IN THE TESTS.

Mark	Chemical Composition, per cent							Rolled to	Preliminary Heat Treatment	Heat Treated by Laboratory No.
	Carbon	Manganese	Phosphorus	Sulfur	Silicon	Chromium	Molybdenum			
K1[a]	0.17	0.42	0.012	0.035	....	....	....	1 in. round	1650 to 1700° F. (900 to 925° C.), 1 hour cooled in air.	23
K2[b]	0.38	0.35	0.011	0.030	0.31	13.48	....	1 in. round	1650° F. (900° C.), 72 hours cooled in air; 1800° F. (980° C.), 2½ hours cooled in oil; 1250° F. (675° C.), 3 hours cooled in oil.	44
K3[a]	0.39	0.51	0.015	0.029	0.19	0.87	0.21	1⅛ in. round	1625° F. (880° C.), 2 hours cooled in air; 1550° F. (845° C.), 1½ hours cooled in oil; 1300° F. (705° C.), 2 hours cooled in oil.	13

[a] Analysis made by manufacturer of the steel.
[b] Analysis made by laboratory No. 18.

In Fig. 4 the stress-strain relations obtained at the different laboratories are plotted to one set of coordinates for each test temperature. The values of the proportional limits originally selected by each laboratory are shown by the short lines which run at about 90 deg. to the modulus line or the slope of the stress-strain curve as the case may be. The cooperators did not all use the same coordinates originally in plotting the stress-strain curves and the designated

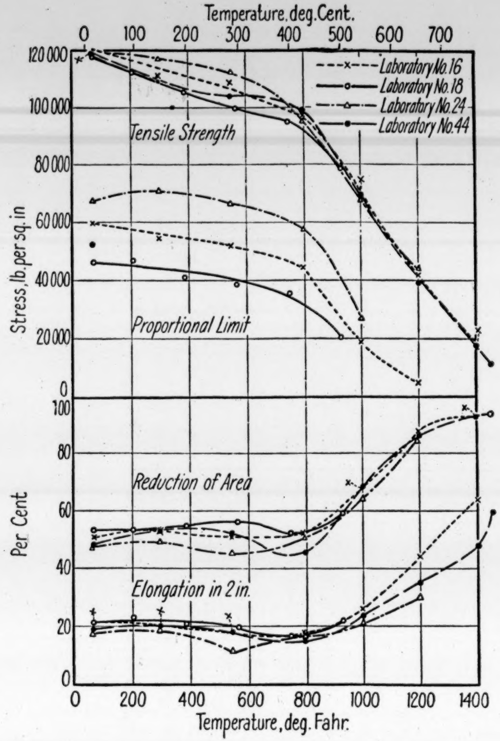

FIG. 1.—Effect of Temperature on the Tensile Properties of a High-Chromium (Stain-Resisting) Steel as Determined by Four Different Laboratories.

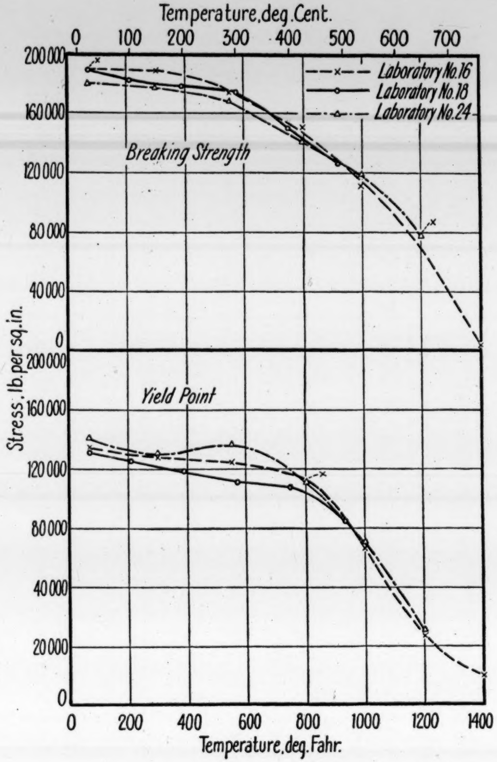

FIG. 2.—Effect of Temperature on the Yield Point and Breaking Strength of a High-Chromium (Stain-Resisting) Steel as Determined by Three Different Laboratories.

Breaking strength refers to the load in pounds at the moment of fracture divided by the area in square inches at the fractured section.

values of the proportional limits may therefore not be in close agreement with the values which would be selected from the curves in Fig. 4.

The subcommittee does not feel justified at this time in commenting further on these results except to point out that there are variations which indicate that not all of the important factors in the testing technique were under control. The same viewpoint was reached from comparative tests on steels K1 and K3, previously reported, and made it desirable to secure more detailed information concerning the equipment and procedure employed.

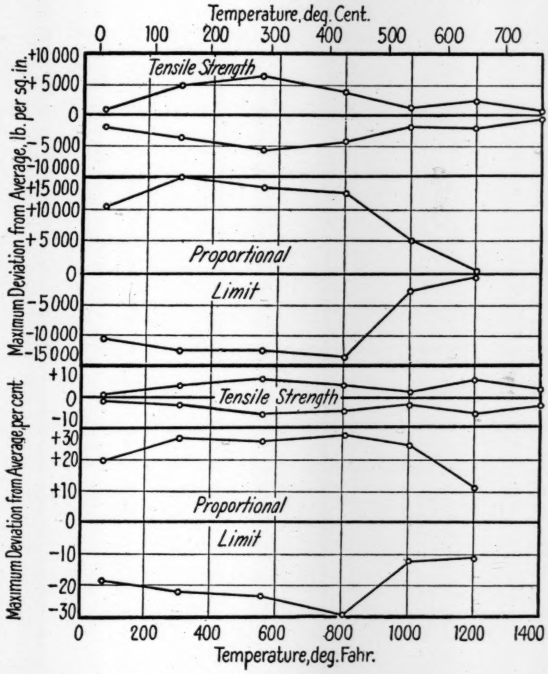

FIG. 3.—Maximum Deviation from the Average Values of Tensile Strength and Proportional Limit in the Described Tests at Different Temperatures.

Based on data shown in Figs. 1 and 2 for the high-chromium steel, K2.

SOME FACTORS INFLUENCING THE TEST RESULTS

While attempts have been made during the past year to isolate individual variables contributing to the observed variations in the tensile properties reported by different laboratories for the same steels, it may be stated that the subcommittee has not been able to determine the magnitudes of the effects produced by variations in tempera-

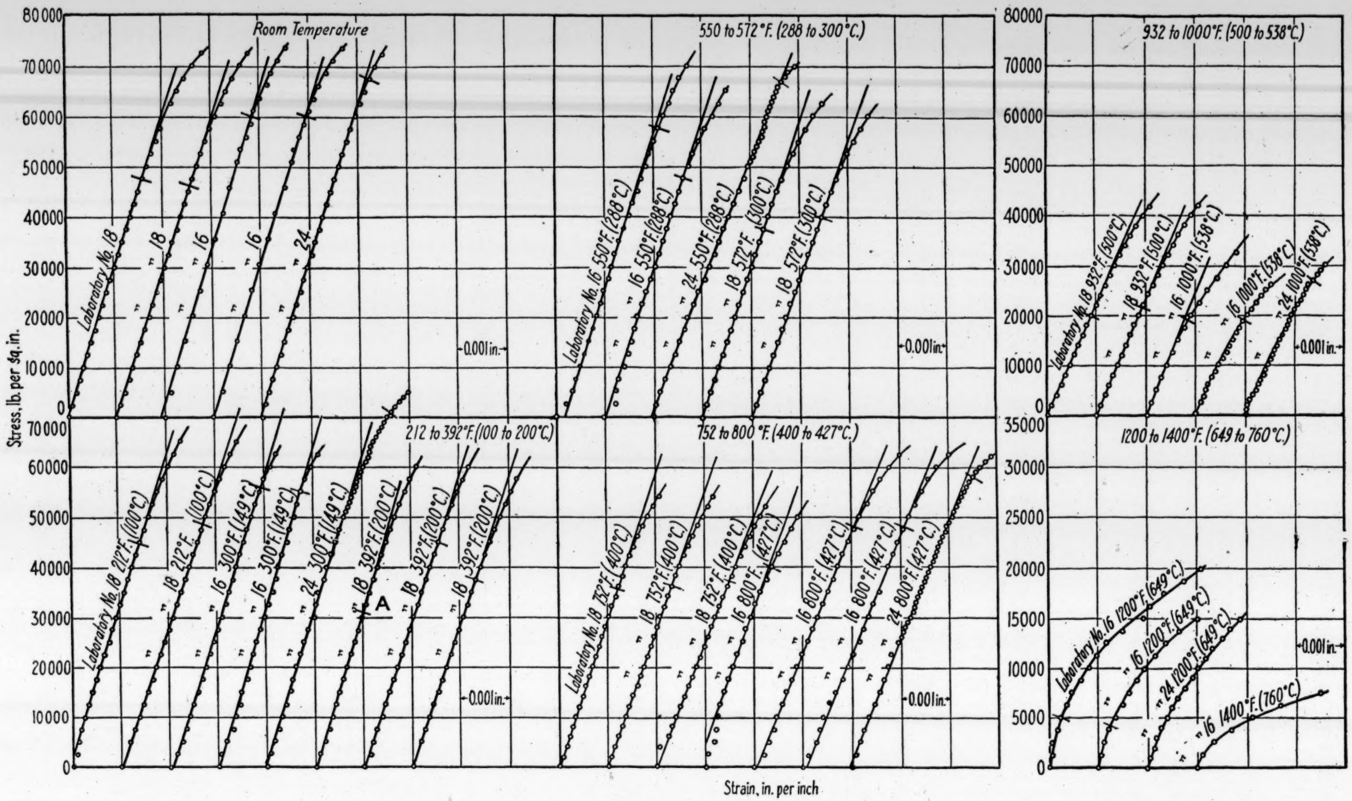

FIG. 4.—Stress-Strain Curves at Different Temperatures Reported by the Different Cooperators for the High-Chromium (Stain-Resisting) Steel, K2.

The test marked *A* was not included in the average values of proportional limit because of temperature variations.

ture uniformity, pulling speeds, methods of measuring temperatures, sizes and types of furnaces, etc. However, a study of the details of equipment and methods used by the different cooperators has shown certain general trends and it is felt that some general recommendations can now be made concerning some of the conditions under which high-temperature tensile tests should be carried out.

Pulling Speeds:

It was not practicable to develop detailed information on the rates of stress increase below the proportional limit since the equipment used in a majority of cases required that the loads be increased in steps to permit strain readings corresponding to definite stresses. However, some wide variations were reported in the pulling speeds used above the proportional limits or yield points. These varied from 0.02 to 0.40 in. per minute, a twenty-fold variation (Table II) and at the highest test temperatures around 900 to 1200° F. (480 to 650° C.), where the time factor becomes of considerable importance, such variations in the pulling speed may make a considerable difference in the reported values of the tensile strength. For example, the differences for steels K1 and K3 at 1000° F. (540° C.) were around 15 to 20 per cent and at 1200° F. (650° C.) were around 35 per cent. These differences are probably not solely the result of variations in the pulling speeds but the cooperators using the highest pulling speeds consistently reported the highest tensile strengths. At somewhat lower temperatures, around 800° F. (425° C.) or below, the effects of variations in pulling speed were not so marked.

TABLE II.—SOME DETAILS OF THE MECHANICAL EQUIPMENT USED BY THE COOPERATORS.

Laboratory (designated by number)	Diameter of Specimens Used, in.	Pulling Speed Beyond Yield Point, in. per minute	Type of Extensometer Used[a]	Claimed Sensitivity of Extensometer, in.[b]	Type of Testing Machine Used
No. 20	0.505	0.087	Internal (Dials)	0.00002	Amsler Hydraulic
No. 13	0.505 and 0.250	0.02 to 0.05	Internal (Mirrors)	0.000004	Amsler Hydraulic
No. 22	0.505	0.125	Internal (Dials)	0.00001	
No. 23	0.505	0.40	Internal (Optical)	0.00005	Riehle 3 screw
No. 24	0.505	0.146	?	0.00001	
No. 3	0.250	0.09	External (Dials)	0.00005	
No. 2	0.505	0.40	Internal (Dials)	0.0001	Olsen
No. 50	0.505	0.10	External (Dials)	0.0005	Olsen gear driven
No. 53	0.505	0.083	Internal (Martens)	0.000006	
No. 16	0.500	0.10	Internal (Lever and Dial)	0.000025	Olsen gear driven
No. 18	0.505	0.05 to 0.10	Internal (Martens)	0.00001	Amsler Hydraulic
No. 44	0.505	0.16			

[a] Internal extensometer attachment to specimen is made within the furnace at points 2 in. apart on reduced section. External extensometer attachment to specimen or adapters is made at points outside the furnace.

[b] Actual measured length.

The subcommittee recommends that all future tests be made at pulling speeds between 0.05 to 0.10 in. per minute after the propor-

TABLE III.—TEMPERATURE VARIATIONS FOUND IN TESTS MADE BY THE DIFFERENT COOPERATORS.

Cooperators (designated by number)	Position for Measuring Specimen Temperature[a]	Temperature Differences Between Points, deg. Fahr. (Centigrade equivalents are given in parentheses)															Amount Which Center is Hotter than Usual Couple Position, deg. Fahr. (Centigrade equivalents are given in parentheses)					Maximum Temperature Difference in Gage Length Points C, T and B,[b] deg. Fahr. (Centigrade equivalents are given in parentheses)				
		$(C_i - T_i)$[b]					$(T - B)$[b]					$(C_o - C_i)$[b]														
		300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000 °F. (540° C.)	1200° F. (650° C.)	300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000° F. (540° C.)	1200° F. (650° C.)	300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000° F. (540° C.)	1200° F. (650° C.)	300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000° F. (540° C.)	1200° F. (650° C.)	300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000° F. (540° C.)	1200° F. (650° C.)
No. 20	Hole in fillet	9 (5)	18 (10)	52 (29)	48 (26)	..	1 (0.6)	−4 (−2)	−6 (−3)	4 (2)	..	15 (8)	29 (16)	14 (8)	34 (19)	..	6 (3)	14 (8)	35 (19)	36 (20)	..	10 (6)	18 (10)	52 (29)	52 (29)	..
No. 13	Hole in test bar (diameter):																									
	0.505 in.	..	..	..	..	34 (19)	..	..	..	..	−14 (−8)	..	..	..	..	..	13 (7)	34 (19)	48 (27)	79 (44)	113 (63)	18 (10)	25 (14)	45 (25)	115 (64)	34 (19)
	0.250 in.	18 (10)	25 (14)	45 (25)	115 (64)	..	−9 (−5)	−16 (−9)	−24 (−13)	−58 (−32)	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 22	Center at surface	−4 (−2)	0	0	−4 (−2)	−4 (−2)	8 (4)	5 (3)	5 (3)	0	4 (2)	0	0	5 (3)	4 (2)	4 (2)	0	0	−5 (−3)	−4 (−2)	−4 (−2)	8 (4)	5 (3)	5 (3)	4 (2)	4 (2)
No. 23	Top inside	−10 (−6)	0	0	0	5 (3)	15 (8)	5 (3)	10 (6)	5 (3)	5 (3)	25 (14)	30 (17)	15 (8)	30 (17)	40 (22)	0	−5 (−3)	−5 (−3)	0	0	15 (8)	5 (3)	10 (6)	5 (3)	10 (6)
No. 24	Hole in fillet	..	7 (4)	0	9 (5)	..	..	0	0	−12 (−7)	..	..	18 (10)	19 (11)	12 (7)	..	..	75 (42)	120 (67)	153 (85)	..	..	..	..	..	..
No. 3	Center at surface	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
No. 2	Center at surface	8 (4)	−1 (−0.6)	..	23 (13)	85 (47)	−3 (−2)	18 (10)	..	−3 (−2)	−2 (−1)	12 (7)	29 (16)	..	40 (22)	40 (22)	−12 (−7)	−29 (−16)	..	−40 (−22)	40 (22)	8 (4)	8 (4)	17 (9)	23 (13)	85 (47)
No. 50	Center at surface	−14 (8)	−19 (−11)	−19 (−11)	−21 (−12)	−23 (−13)	24 (13)	79 (44)	70 (39)	91 (51)	97 (54)	14 (8)	19 (11)	19 (11)	21 (12)	23 (13)	−14 (−8)	−19 (−11)	−19 (−11)	−21 (−12)	−23 (−13)	24 (13)	79 (44)	70 (39)	91 (51)	97 (57)
No. 53	Center at surface	(Maximum variation claimed not greater than 10° F. (6° C.))																				(Claimed not greater than 5° F. (3° C.))				
No. 16	Center at surface	13[c] (7)	16[c] (9)	16[c] (9)	12[c] (7)	11[c] (6)	..	..	..	..	..	10 (6)	7 (4)	4 (2)	3 (2)	2 (1)	−10 (−6)	−7 (−4)	−4 (−2)	−3 (−2)	−2 (−1)	13 (7)	16 (9)	16 (9)	12 (7)	11 (6)
No. 18	Center at surface	13 (7)	30 (17)	46 (26)	63 (35)	..	5 (3)	−5 (−3)	−23 (−13)	−41 (−23)	..	24 (13)	31 (17)	22 (12)	15 (8)	..	−24 (−13)	−31 (−17)	−22 (−12)	−15 (−8)	..	13 (7)	30 (17)	46 (26)	63 (35)	..
No. 44	Center at surface	Estimated temperature drop 10 to 15° F. (6 to 8° C.) over 2-in. gage length.																								

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[a] Test specimens 0.505 in. in diameter used for both the tensile tests and calibration bars unless otherwise indicated, in Table II.

[b] C = Center of gage length.
T = Top of gage length in a specimen placed in the vertical position.
B = Bottom of gage length in a specimen placed in the vertical position.
The subscript o refers to temperature measurements at the surface (outside) of the specimen; and i to positions beneath the surface (interior).

tional limit or yield point has been passed. A specification permitting only one pulling speed would be desirable but could not readily be adhered to since many of the testing machines available have gear drives and the choice of pulling speeds is therefore limited.

It is further recommended that the measurements of stress and strain be taken as rapidly as is consistent with accuracy. In no case, however, should this rate of stress increase below the proportional limit exceed the values recommended for use above the proportional limit.

Determination of Test Temperatures:

Temperature variations are to be expected along the length and from center to surface of the test specimens although the magnitude of these variations is dependent upon the equipment used and the care taken in the tests. Direct comparisons of results are justified only when temperatures are measured at corresponding positions in the test specimens or when the temperature measurements at different locations can be expressed accurately in terms of some one position or area in the test specimen.

As is shown in Table III, different locations and methods of attachment of the thermocouples were used by the different cooperators. Some inserted thermocouples directly in holes in the fillet or along the axis to the fillet while others clamped or otherwise held the thermocouples in contact with the surfaces of the specimens. There are disadvantages to insertion within or attachment to the test specimens; insertion within the metal introduces the question of where the thermal junction actually is while attachment to the surface, without shielding, leaves the thermal junction exposed to direct radiation from the furnace walls and the couple tends to register temperatures which are higher than those of the test specimen. With appreciable elongation the attached thermocouple frequently moves from its original location on the surface of the specimen and may even become detached.

The subcommittee favors temperature measurements with thermocouples placed within the test specimen. Not less important is an accurate survey of the temperature variations within the gage length so that the temperature measurements made by different laboratories can be brought to a common basis for comparison.

Table III shows wide variations in the degree of temperature uniformity attained in the tests made by the different cooperators. This is shown in the last column in which the maximum temperature differences within the gage length (positions *C*, *T* and *B*) are summarized. The variations between the temperature at the center of the gage length and the position selected for the thermocouple in carrying out the tensile tests are summarized in next to the last column of Table III but may have little to do with the variations over the gage length of the test specimen. It is obviously impracticable to secure accurate tension test data on specimens having holes drilled for thermocouples within the gage length and some of the laboratories have chosen positions in the fillets for temperature measurements on specimens under test (not for calibration purposes).

TABLE IV.—CORRELATION BETWEEN ARRANGEMENT OF HEATING COILS AND THE TEMPERATURE UNIFORMITY ATTAINED.

Laboratory (designated by number)	Tube length, in.	Inside Diameter of Tube, in.	Tube Material	Type of Winding	Length of Gap or Space at Center, in.	Overall Length of Winding (including gap), in.	Number of Turns in Gap or Center Spaced Winding	Number of Turns in Entire Winding	Size of Wire[a]	Relation of Length of Gap to Winding, per cent	Relation of Resistances in Gap to Entire Winding, per cent	Temperature Difference in Specimen at 1000° F. (540° C.), *C-T* in deg. Fahr.	Temperature Difference in Specimen at 1000° F. (540° C.), C_o-C_t in deg. Fahr.
No. 20	14	2¼	....	Gap	4½	12½	4	25	....	36.0	16.0	48 (27° C.)	34 (19° C.)
No. 13[b]	5½	3	Alundum	Uniform	0	5½	..	20	No. 16	0.0	0.0	115 (64° C.)	?
No. 22	9⅝	3	Alundum	Spaced	2	9⅛	2[c]	16	Ribbon	20.8	0.0?	−4 (−2° C.)	4 (2° C.)
No. 23	12	2	Alundum	Gap	3¾	10¼	3	60	No. 16	36.6	5.0	0	30 (17° C.)
No. 24	9	2½	Silica	Spaced	2½	6½	5[c]	20	⅛-in. ribbon	38.5	0.0	9 (5° C.)	12 (7° C.)
No. 3[b]	6	2¼	Alundum	Uniform	0	6	..	..	No. 22	0.0	0.0	?	?
No. 2	8	2	Alundum	Gap	2½	8	6	50	No. 14	31.3	12.0	23 (13° C.)	40 (22° C.)
No. 50	12	1½	Fire Clay	Uniform	0	11½	..	45	Ribbon	0.0	0.0	−21 (−12° C.)	21 (12° C.)
No. 53	14	3	Alundum	Gap	1½	12	0	?	Ribbon	12.5	0.0	Stated not over 10 (6° C.)	
No. 16	12⅞	2½	Refractory	Uniform	0	12	..	20	No. 14	0.0	0.0	12 (7° C.)	3 (2° C.)
No. 18	9	2½	Vitreosil	Spaced	⅞	8⅛	9	32	Coiled ribbon	50.0	28.0	63 (35° C.)	15 (8° C.)
No. 44	9	1	....	Gap	..	...	..	..	....	....	....	Estimated 10 to 15 (6 to 8° C.)	

[a] B. & S. gage unless otherwise designated.

[b] Arranged for cutting out parts of the circuit.

[c] Part or all of the test specimens used by these cooperators were 0.25 in. in diameter instead of 0.505 in.

The fact that these selected locations are at temperatures appreciably below those of the gage length does not indicate correspondingly wide variations within the gage length (see data for laboratories Nos. 13 and 24).

Types of Furnace Windings:

If auxiliary coils used by laboratories Nos. 24 and 22 are disregarded then the furnace windings used by the different cooperators come under three headings, (*1*) uniformly spaced windings from end to end, (*2*) windings which are spaced further apart at the center than at the ends, and (*3*) so-called gap-wound furnaces in which there is a space or gap between the two end windings.

The data recorded in Table IV indicate that the spaced or gap-wound coils gave greater temperature uniformity than the uniformly spaced windings. In making this statement the results obtained by laboratory No. 16 (Table IV) have been disregarded since a commercial furnace was used, the detailed construction of which was not known.

With the uniformly spaced winding from end to end the center of the specimen is normally at a higher temperature than the ends, and because of this the recommendation is made that all future tests be made in furnaces in which the coils are spaced further apart at the center than at the ends unless auxiliary windings are used to promote temperature uniformity. This simply means that provision should be made to compensate for the increased center temperatures in furnaces heated by uniformly spaced windings.

Other variables in furnace design appear to be of somewhat less importance with regard to the results obtained. The tubes or "cores" upon which the resistors were placed were all non-metallic and a majority of the cooperators used alundum. Tube diameters varied from 1 to 3 in. (Table IV) but there is nothing to indicate that these variations or differences in the tube length from 5½ to 12½ in. exerted any marked effects upon the results obtained on specimens having a 2-in. gage length.

For example, Table IV shows that the temperature differences (C-T) at 1000° F. (540° C.) reported by laboratories Nos. 50 and 16 with tube lengths of 12 in. were smaller than those reported by laboratories Nos. 13 and 18 with tube lengths of 5½ in. and 9 in. respectively. However, laboratory No. 20 with the longest tube used by any of the cooperators reported temperature variations twice as large as those from laboratories Nos. 50 and 16. Also the temperature differences reported by laboratory No. 2 with an 8-in. tube length were practically identical with those from laboratory No. 50 with a 12-in. tube length.

In Table III, laboratory No. 13 reported a temperature difference ($C_i - T_i$) at 1000° F. (540° C.) of 115° F. (64° C.) which was obtained using a test bar 0.250 in. in diameter. This was probably caused by the design of the upper adapter, and should not be used as evidence for or against a certain tube length. This is evident from the much smaller temperature variations reported for the same furnace at 800 and 1200° F. (425 and 650° C.) but using a test bar 0.505 in. in diameter and a different adapter. Furthermore, although laboratory No. 50 reported temperature differences, $C_i - T_i$ at 1000° F. (540° C.) much less than laboratories Nos. 13 and 18, just the reverse is the case when temperature differences over the whole gage length are considered. Here both laboratories Nos. 13 and 18 reported smaller temperature variations than laboratory No. 50 which used the longer tube.

The important point with respect to furnace design is the production of temperature uniformity within the gage length of the test specimens, but as is shown by the locations of the fractures recorded in Table V, this was not always achieved. When the temperatures at the center of the gage length were higher than at the ends the fractures quite generally, though not invariably, occurred at the center.

TABLE V.—LOCATION OF FRACTURES IN TEST SPECIMENS.

Laboratory (designated by number)	Metal Tested	Location of Fracture at Test Temperature						Center Hotter than End[a]
		70° F. (20° C.)	300° F. (150° C.)	550° F. (290° C.)	800° F. (425° C.)	1000° F. (540° C.)	1200° F. (650° C.)	
No. 20	K1	Central	Out	Central	Central	Central	......	Yes
No. 13	K3	1 Low 1 High	High	1 High 1 Central	Central	Central	Central	Yes
No. 22	K3	Central	High	High	Central	Central	Central	No (?)
No. 23	K1 K3	Central Central	Low Low	Central High	High High	Low High	High High	No
No. 24	K2	......	......	......	......	......	......	
No. 3	K1	1 Central 1 Out	Out	Central	1 Central 1 Out	Central	Central	Yes
No. 2	K3	Central	High	Low	Low	High	High	Yes
No. 50	K4	Central	Central	Low	High	High	High	No
No. 53	K1	......	......	......	......	......	......	
No. 16	K2	Central 1 High	1 Central 1 High	1 High 1 Low	1 Central 2 Low	High	2 Central	Yes
No. 18	K2	2 High	2 High	2 High	1 Central 2 High	2 Central	......	Yes

[a] From data in Table III.

The whole problem of furnace design may be summed up by pointing out that the principal object of the heating unit is to produce constant and uniform temperatures throughout the gage length of the test specimens. The reported variations in design and results of tension tests clearly indicate that more attention must be paid to the details of construction of the heating units than has been given to this subject in the past if uniform results are to be expected at different laboratories. This object will be more nearly achieved, (1) with standardized pulling speeds, (2) with spaced or gap-wound furnaces or by the use of auxiliary end resistances to promote temperature uniformity, and (3) with temperature measurements within the metal of the test specimen. However, there is need for more detailed recommendations concerning the construction of heating units and the subcommittee recommends that this subject be investigated experimentally with the support of the main committee.

Strainometers and the Plotting of Stress-Strain Curves:

The methods used in plotting the stress-strain data may prove to be an important factor in the final determination of the proportional limit value. If proportional limits are to be comparable, it is obvious that not only must variations in the methods or operations of testing be eliminated in so far as possible but that ordinates used for plotting the data be determined by the accuracy and sensitivity of the strain measurements.

In the hope of insuring the use of uniform methods of plotting data by the cooperating laboratories, and thus making the results comparable, the committee originally recommended in its procedure for short-time tension tests the use of the following coordinates:

FOR RANGES OF STRESS ON 0.505-IN. BARS	STRESS SCALE TO BE USED FOR ORDINATE	STRAIN SCALE TO BE USED FOR ABSCISSA
14 000 to 28 000 lb.	4000 lb. per linear in.	0.004 in. per linear in.
7 000 to 14 000 "	2000 " " " "	0.002 " " " "
3 000 to 7 000 "	1000 " " " "	0.001 " " " "
Below 3 000 "	500 " " " "	0.0005 " " " "

In checking over the stress-strain curves submitted by the cooperating laboratories, it at once became evident that the suggested coordinates did not meet with general approval. Strain values were found plotted to abscissas ranging from 0.2 to 0.0002 in. per linear inch. The coordinates selected by the committee permitted the plotting of strain at low stresses eight times as accurately as the strain at high stresses, but the coordinates actually used at one temperature resulted in one laboratory plotting its strain data 200 times as accurately as another. Presumably the variations from the proposed scheme for plotting were due to either one of two reasons. Either the cooperating laboratory desired to use a system of coordinates permitting greater accuracy in plotting so that it might fully utilize the sensitivity of its extensometer, or it desired to use the same coordinates for all data regardless of the stress range.

As a result of these deviations from the proposed scheme of plotting, several instances were found where an appreciable lowering of the proportional limit would have been obtained if the data were to be replotted using other coordinates. In other instances a slight raising of the proportional limit would have resulted. Lowering of the proportional limit by replotting was particularly marked for data obtained with extensometers of high sensitivity but not plotted to strain coordinates permitting corresponding accuracy in plotting.

For example, strain data for tests at 1200° F. (650° C.) with extensometers reading to millionths of an inch were reported by two of the cooperating laboratories. One plotted the data to coordinates of 500 lb. per sq. in. per linear inch and 0.0001 in. per inch per linear inch. The other used coordinates of 10,000 lb. per sq. in. per linear inch and 0.004 in. per inch per linear inch. Although both obtained strain measurements with extensometers reading directly to millionths of an inch, one laboratory plotted the strain forty times as accurately as the other.

Another variation in the methods of plotting was the use of different ratios of stress and strain. Decrease in the strain unit per linear inch without change in the stress unit per linear inch results in a more marked deviation from the assumed proportionality between stress and strain; that is, a deviation which might appear questionable with a one to one ratio of the stress-strain coordinates, becomes very definite when the strain unit is changed to give a two to one ratio. This in effect brings about a lowering of the proportional limit.

A study of the curves and data submitted suggests that all strain data should be plotted with a degree of accuracy in keeping with the sensitivity of the extensometer used and that the same coordinates should be used for all data, regardless of the test temperature or the stress range covered.

Following the plotting of the stress-strain data, a very important factor enters into the final determination of the proportional limit value. Different methods of plotting may cause appreciable differences in the values selected for the proportional limit, but these differences may be small in comparison to those which may be introduced in the placing or drawing of the stress-strain curve. Unless the observed relations between the stress and strain values are to differ greatly from those reported to the committee to date, a decision must invariably be made as to whether or not certain plotted points are to be ignored in placing the stress-strain curves. This factor is one which cannot be ignored and yet is one for which instructions cannot well be prepared, without a mathematical analysis of the data.

An appreciation of the influence of the selection of coordinates, accuracy in plotting, use of the same coordinates and the placing of the stress-strain curve on the proportional limit value may be gained by a comparison of the values shown in Fig. 4. The stress-strain relations obtained at the different laboratories for the high-chromium steel, K2, are plotted to one set of coordinates for each test temperature. The values of the proportional limits originally selected by each laboratory, and which are indicated by short lines run at about 90 deg. to the slope of the stress-strain diagram, vary in a number of instances very appreciably from the values which would be selected from the curves of Fig. 4.

Respectfully submitted,

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Subcommittee on Analysis and
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APPENDIX II

SOME LONG-TIME TENSION TESTS OF STEELS AT ELEVATED TEMPERATURES

BY J. J. KANTER[1] AND L. W. SPRING[2]

SYNOPSIS

Several long-time tension tests on carbon cast steel are reported that indicate constantly decelerating rates of creep during testing periods up to one year at temperatures of 800 to 1000° F. (425 to 540° C.). Evidence of similar behavior at higher temperatures is given for other steels.

Creep stresses defined in terms of total creep per life period instead of rates of creep are used, because rates of creep are not constant, though they are indicative. Stresses yielding creep of 0.1 per cent for 10,000 hours, 1 per cent for 10,000 hours, and 10 per cent for 10,000 hours are estimated from the data given.

Short-time tensile stresses are shown in comparison with creep stresses for several steels. In general these comparisons indicate that short-time tests do not reliably reflect long-time tests at temperatures above the blue-brittle and corresponding ranges.

A number of flow curves given for the various steels, when plotted logarithmically, approximate straight lines. The slopes of these lines suggest a quantitative means of comparing the effects of strain-hardening accompanying creep.

Above the equi-cohesive temperature (at 1000° F. (540° C.)) cast and wrought steel of identical composition differ in their creep characteristics, the cast material being less yielding.

A chromium-tungsten steel (6½ per cent chromium, 6½ per cent tungsten) was found to flow considerably less in the annealed condition than as oil quenched and drawn, when tested at temperatures of 1000, 1200 and 1400° F. (540, 650 and 760° C.).

Austenitic chromium-nickel steel (18-8 alloy) when water quenched from 2100° F. (1150° C.) and therefore of large grain size is more resistant to flow than it is in the unaltered rolled condition, as shown by comparative tests at 1200, 1400 and 1600° F. (650, 760, and 870° C.).

It is apparent that treatments which produce increased grain size reduce creep in metals at elevated temperatures above the equi-cohesive temperature.

In presenting some data for carbon cast steel,[3] the authors showed estimates on length of time to produce 1 per cent of flow at stresses near and below the proportional limit, in the temperature range of 750 to 1200° F. (400 to

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[3] J. J. Kanter and L. W. Spring, "'Long-Time' or 'Flow' Tests of Carbon Steels at Various Temperatures with Particular Reference to Stresses Below the Proportional Limit," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 80 (1928).

650° C.)—these values based largely upon tests not over 1000 hours in duration. It was intimated that several of the tests at stresses and temperatures of particular interest were being continued for somewhat longer periods of time in order to secure more reliable and better substantiated curves. Some of these tests on annealed carbon cast steel are shown in Figs. 1 and 2. These flow-time curves are of the order of a year's duration at a single stress and temperature—800, 900 and 1000° F. (425, 480 and 540° C.) being represented. These curves, generally speaking, are characterized by decreasing rates of creep or flow. Considering the 0.40-per-cent carbon cast steel tested for 365 days (8760 hours) at 1000° F. (540° C.) and 4000 lb. per sq. in. (Fig. 1), the creep rate could be taken for linear at almost any portion of the curve when considering only a few hundred hours or even two thousand hours of testing, but for the range of an entire year, decided deceleration of creep is shown. A similar case exists in 0.33-per-cent carbon cast steel, 800° F. (425° C.), 10,000 lb. per sq. in., 307 days (7368 hours) (Figs. 1 and 2) where the total amount of creep involved is less than one-thirtieth of that in the 1000° F. (540° C.) curve. The 900° F. (480° C.) curve (Fig. 1) shows a more nearly constant creep rate than the other two. Such curves, and others in the following diagrams, indicate that creep rates are not necessarily linear even at temperatures usually considered to be above the strain-hardening range.

TABLE I.—ANALYSES OF MATERIALS USED.

		Si	Mn	S	P	C	Ni	Cr	Mo	W
	Group	Silicon, per cent	Manganese, per cent	Sulfur, per cent	Phosphorus, per cent	Carbon, per cent	Nickel, per cent	Chromium, per cent	Molybdenum, per cent	Tungsten, per cent
Cast Steel, Carbon	No. 150 No. 150F	0.24	0.60	0.033	0.032	0.20	....	....	....	....
Cast Steel, Carbon	No. 117	0.34	0.77	0.029	0.032	0.33	....	....	....	....
Cast Steel, Carbon	No. 136	0.32	0.70	0.015	0.022	0.40	....	....	....	....
Cast Steel, Nickel-Chromium	No. 116	0.28	0.57	0.015	0.011	0.40	2.03	0.82	....	....
Cast Steel, Nickel-Chromium { As Cast Forged	No. 158 No. 158F	0.29	0.58	0.010	0.017	0.41	2.00	0.87	....	....
Open-Hearth Iron Rod	No. 143	0.03	0.02	0.028	0.008	0.01	....	....	....	....
Low-Carbon Steel Rod	No. 120	0.02	0.47	0.037	0.004	0.17	....	....	....	....
Medium-Carbon Steel Rod	No. 140	0.06	0.64	0.024	0.012	0.35	....	....	....	....
Medium-Carbon Steel, Forged	No. 97	0.06	0.53	0.048	0.021	0.41	....	....	....	....
Chromium-Nickel Steel	No. 157	0.25	0.56	0.015	0.013	0.46	1.34	0.50	....	....
Chromium-Nickel Steel	No. 122	....	0.63	0.028	0.054	0.31	1.18	0.63	....	....
Chromium-Molybdenum Steel	No. 123	0.24	0.48	0.017	0.011	0.37	....	0.91	0.24	....
Stainless Iron, 12 per cent Chromium	No. 148	0.32	0.56	....	....	0.12	....	12.23	....	....
Austenitic Chromium-Nickel Steel, Forged	No. 160	0.43	0.51	....	....	0.10	9.35	19.82	....	....
Austenitic Chromium-Nickel Steel { Rolled Quenched	No. 171 No. 171A	0.70	0.50	....	....	0.04	9.74	19.02	....	....
Chromium-Tungsten Steel	No. 159 No. 159A	0.97	0.33	....	....	0.57	....	6.44	....	6.63

S.T. [illegible] 18

The creep value of 0.1 per cent in 10,000 hours, then, represents a condition of minute creep, at which, as tests show, the creep rate often decelerates greatly after a few thousand hours. If a total life period of 100,000 hours is considered, indications are that the creep occurring during the 90,000 hours in excess of the time included by 0.1 per cent for 10,000 hours, may amount to only a fraction of 1 per cent; the value 1 per cent per 100,000 hours used as a basis for creep stresses by several investigators was accepted by them on the assumption that a constant creep rate persists after an initial rapid creep for usually not more than one or two hundred hours. A stress yielding 0.1 per cent for 10,000 hours represents the same order of rigidity and avoids the arbitrary assumption necessary to define 1 per cent per 100,000 hours. Similar reasoning may be used in defining 1 per cent for 10,000 hours and 10 per cent for 10,000 hours to be representative of less rigorous creep stresses for purposes where such are permissible and desirable. In this way the definition of creep values is confined to terms interpreting more nearly what has actually been observed during feasible testing periods.

In view of these facts we are not justified, strictly speaking, in defining creep stress in terms of creep rates persisting throughout the life period in question. Obviously defining a stress, for example one yielding 1 per cent of elongation per 100,000 hours, is inexact if flow comes practically to a standstill after a few thousand hours' stressing. It is therefore much more in accordance with observation to define stresses yielding a given amount of creep per life period, as for instance 0.1 per cent for 10,000 hours, 1 per cent for 10,000 hours or 10 per cent for 10,000 hours, these conveying a wide range of applicability.

Although no portion of the flow-time diagram can be taken as representing a definite rate of creep, it has been shown by us and by others that estimates of deformation based upon such curves, while not establishing absolute values, are at least conservative engineering criteria and usually establish an upper limit to the subsequent rate of flow, that is, a maximum value.

APPARATUS AND METHODS

The apparatus and methods used in carrying out the tests herein given are essentially the same as was described in our previous article.[1]

Briefly described, the long-time testing equipment consists of twelve long-time testing units, the loading for each being accomplished through a simple, knife-edge supported lever, giving a high degree of accuracy in the load attained. The specimens used are the standard specimens 0.505 in. in diameter for all loads up to 40,000 lb. per sq. in. The furnaces are gap-wound and carefully adjusted to give uniform temperature over the 2-in. breaking section. A continuous record of the temperature of the specimen in each machine is kept by means of a 12-point Leeds & Northrup recorder. Temperature control is attained by using a separate Leeds & Northrup controller for each unit, acting through a relay, which, together with a double plate rheostat, regulates a portion of the current necessary for maintaining testing temperature. The temperature fluctuations with control couple placed in the test specimen usually are less than 5° F. (3° C.) and interruption of heating is guarded against by having two separate power lines supplying the installation so arranged that one of the two circuits is always kept closed automatically.

Measurement of elongation is taken by means of a telescope fitted with a filar eyepiece and mounted on a micrometer slide. The telescope is used portably at each unit by attaching to a steel post fixed in each lower cross head casting. Elongation readings reproducible to 0.00005 in. in the 2-in. gage length are obtained by focusing through a slit in the furnace and measuring the distance between a fine platinum wire fastened against the lower fillet of the test specimen and the end of a platinum strip riveted to the bar above the upper fillet and extending low enough almost to meet the wire.

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[1] *Loc. cit.*

Short-time testing is done in a three-screw Riehle machine of 50,000-lb. capacity. An extensometer attached directly to the breaking section of the specimen within the furnace is used. Strain readings are obtained as the average given by two dial gages graduated to read to 0.0001 in. and mounted so as to measure the strain on opposite sides of the specimen.

LOGARITHMIC PLOTTING OF RESULTS

For the sake of compactness a number of the flow-time curves here presented are plotted with logarithmic time and creep ordinates, using one day and 0.0001 in. per inch (0.01 per cent) as origin. Using this scheme a complete series of tests comprising various temperatures and stresses is shown on a single diagram. When using straight coordinates, small amounts of creep must be represented on a very constricted scale if given on the same coordinates with rapid creep data, or plotted separately with a magnified elongation scale if minute characteristics are to be made apparent.

Aside from the condensed presentation possible with logarithmic plotting of flow-time curves, certain advantages of interpretation are afforded. Examination of Figs. 9 to 15 reveals the interesting fact that many of the curves take the form of straight or nearly straight lines for the entire range of flow investigated. Some of the tests of more than usual duration following this relationship are listed:

	Group		Temperature, deg. Fahr.	Stress, lb. per sq. in.	Duration	
					Hours	Days
Fig. 9	No. 117	0.33-per-cent Carbon Cast Steel	800	10 000	7296	304
	No. 150	0.20-per-cent Carbon Cast Steel	800	10 000	4032	168
	No. 117	0.33-per-cent Carbon Cast Steel	900	7 500	7368	307
Fig. 10	No. 116	Nickel-Chromium Cast Steel	800	20 000	1200	50
Fig. 11	No. 120	0.17-per-cent Carbon Open-Hearth Steel Rod	1000	3 000	2808	117
Fig. 12	No. 123	Chrome Molybdenum Steel	800	40 000	1440	60
Fig. 13	No. 157	Nickel-Chromium Steel	800	20 000	2088	87
Fig. 13	No. 157	Nickel-Chromium Steel	1000	3 000	2376	99
Fig. 14	No. 148	Stainless Iron	1000	3 000	5016	209
Fig. 15	No. 160	Austenitic Nickel-Chromium Steel	1400	5 000	1104	46

A number of others for periods up to 1000 hours are given in the diagrams and exhibit a similar relationship. Obviously if this relationship is general, logarithmic plotting affords a convenient device for estimating or anticipating long-time creep curves with tests of only a few hundred hours' duration. It should be remembered, however, that such a practice would be hazardous unless actual tests of appreciable length were carried out on each material in question, establishing the validity of such a means of approximation. It appears from some of the above tests that the straight-line graph may obtain, at certain temperatures, for low-carbon steels, chromium iron, and other steels. It is to be hoped that more long-duration data will soon be forthcoming. Constant load and temperature, maintained for thousands of hours, are essential to test the reliability of this interesting relationship.

In the middle of Fig. 10 for nickel-chromium cast steel, four straight-line logarithmic flow-time curves are seen approximately to intersect at a point corresponding to 6 days' duration and about 0.0017 in. per inch flow. These curves cover a temperature range from 550 to 1200° F. (290 to 650° C.), with stresses from 60,000 to 1000 lb. per sq. in. The slopes of these curves ascend in the order of their temperatures, from horizontal (zero slope) at 550° F.

(290° C.) under 60,000 lb. per sq. in., to about 45 deg. (unit slope) at 1200° F. (650° C.). It is readily recognized that this arrangement is due to the decrease of strain hardening as the temperature rises, which in straight plotting would give curves ranging from parabolic to linear. Hence, the logarithmic chart seems a convenient means for evaluating the degree of strain hardening revealed by creep data. A slope of zero means obviously that the curve is horizontal and that strain hardening sufficient to completely arrest creep has rapidly taken place, a slope of unity (45 deg.) shows immediately that creep is continuous, while values between zero and unity correspond to varying degrees of creep deceleration or strain hardening effect.

Slopes greater than unity may be interpreted in two ways. If the flow is large enough to cause necking in the specimens, obviously the final rapid stretch to rupture gives a steep logarithmic curve. However, small amounts of creep in ductile specimens, giving steep curves, do not necessarily mean that final flow to rupture is reached. Such a condition might be caused by structural changes within the metal itself, tending toward an increasing rate of creep. Something of this nature seems to have occurred in the 365-day (8760-hour) tests of 0.40-per-cent carbon cast steel at 1000° F. (540° C.), 4000 lb. per sq. in. (Figs. 1 and 9). For the first 30 days' testing, the curve is concave upwards, and for the remaining 11 months, concave downwards. We possibly may assume that whatever readjustment took place in this sample, it reached completion after a month under stress and temperature and then flow continued under strain-hardening conditions.

A great number of irregularities in creep curves seem to occur in special alloy steels at temperatures where creep is accompanied by complex structural changes. The scope of the present paper does not warrant a detailed discussion of observations with regard to such changes occurring during creep testing, but an example of this effect may be pointed out in Fig. 15 for austenitic nickel-chromium steel at 1600° F. (870° C.) and 1000 lb. per sq. in. where the creep rate definitely increased after 8 or 9 days' testing.

Studies of the slopes found in flow-time logarithmic plots may be of value as clues toward revealing some of the fundamentals of creep characteristics of metals. As already intimated, the slope values seem to furnish a quantitative estimate of strain-hardening tendencies. For some purposes we might consider the tendency to creep, as being a reciprocal quality of strain-hardening ability. Cohesional forces appear to be a secondary factor in affecting creep at temperatures at which strain-hardening is a considerable factor.

The kind of information available from these slopes is summarized in Figs. 20 and 21. The slope-stress diagrams represented in Fig. 20 afford an interpretation of the limiting creep stress idea. Since a stress function (slope) of zero corresponds to immediate strain-hardening and the slope unity (45 deg.) signifies complete absence of any tendency for creep to cease, we may conclude that the limiting creep-stress must lie below the stress giving a slope of 45 deg. On the 800° F. (425° C.) curves, the slope factors are but slightly affected by wide stress variations. At this temperature, therefore, the choice of a limiting creep stress cannot be made upon a cessation-of-creep basis. Figure 21 is included to show a comparison of the slope temperature relations for some steels. The points upon which these curves are based were arrived at by averaging slopes obtained with various stresses at the respective temperatures.

STEP LOADING

A number of creep investigations have been reported by others in which was used the step loading procedure for determining creep rates. This method was used on the assumption, that, after initial rapid creep, a more or less constant secondary rate obtains, which can be accurately enough determined over a few hundred hours of observation to be used as a basis for estimating creep life. Furthermore, some investigators assume that a nominal amount of total flow, having accumulated from a series of applied stresses, exerts negligible influence on the rate of creep. Such may be the case when testing at temperatures high enough to overcome strain-hardening tendencies, but as demonstrated in some of the tests given elsewhere in this paper, creep must be dealt with even in the presence of very marked strain-hardening effects.

That misleading creep rates are apt to be obtained using the step-loading method is illustrated by Figs. 6, 7 and 8 where tests obtained by both methods are compared. The residual effect of previous creep upon the shapes of the continuations or steps is quite obvious.

Such creep rates, however, must be interpreted with regard to total deformation produced in the prior stress steps. The step method of testing somewhat limits the possibilities of studying the very interesting strain-hardening or creep-hardening phenomena.

EVALUATING CREEP STRESS

As already discussed at some length, creep stress should be evaluated with some regard given to creep hardening. This is accomplished conveniently with the aid of logarithmic flow-time charts. Where extrapolations become necessary, such are conservatively made by projecting the maximum slope occurring on the graph. Creep stress is deduced by semi-logarithmic plotting of stress *versus* time for given deformation, such as 0.1, 1 and 10 per cent. The semi-logarithmic plots are then interpolated for the stresses yielding 0.1 per cent for 10,000 hours, 1 per cent for 10,000 hours and 10 per cent for 10,000 hours.

The stress-temperature diagrams (Figs. 16, 17, 18 and 19) are given with a logarithmic stress ordinate. This is done for the purpose of showing the small stresses at the high temperatures on an open scale. When comparing short-time and long-time tests, conventional stress-temperature plots constrict the creep stresses too much for accurate plotting.

A few general statements may be made regarding correlation of short and long-time tests. As has previously been demonstrated by French,[1] the short-time proportional limit seems to be a good criterion of creep at temperatures up to the blue-brittle range, the maximum temperature that this applies occurring for carbon and many low-alloy steels in the vicinity of 550° F. (290° C.). For some of the high alloy steels, the highest temperature at which the proportional limit is a criterion is somewhat higher, as may be seen from the charts of Fig. 19. The upper limit at which short-time data is a valid criterion depends to a great extent upon the definition accepted for creep stress. If 0.1 per cent for 10,000 hours is considered, the usual proportional limit determinations are unreliable above 550° F. (290° C.), even for many of the special steels.

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[1] H. J. French, "Creep on Five Steels," U. S. Bureau of Standards *Technologic Paper No. 362* (1928).

Using 1 per cent for 10,000 hours, the proportional limit in some instances is a fairly good index up to 1200° F. (650° C.). Yield point may be used up to 550° F. (290° C.) as the limit for not more than 10 per cent of creep in 10,000 hours when considering non-austenitic steel; austenitic steels appear to have a similar relationship at 900 to 1000° F. (480 to 540° C.).

WROUGHT STEEL *versus* CAST STEEL

Some of the results given two years ago[1] suggested that wrought material creeps more rapidly than cast material at temperatures in the vicinity of 1000° F. (540° C.). Forged and cast bars of identical analysis have been tested in both long and short-time tests to throw further light on this matter. Two materials, a 0.20-per-cent carbon cast steel and a nickel-chromium cast steel, are considered, on which some of the coupons, which measured 7 by 1½ by ⅞ in., were forged out to approximately ¾ in. round by 17 in. long (or over twice their original length).

The short-time tension tests (Fig. 18) of these steels show but little difference in strength and yield point between forged and cast bars. Throughout the temperature range the forged carbon steel bars exhibit consistently higher proportional limits than the cast bars. The proportional limit of the nickel-chromium steel drops off suddenly above 800° F. (425° C.) on the forged bars and at 1000° F. (540° C.) on the cast bars. The higher values shown by the forged alloy steel in the lower part of the temperature range probably are attributable to slight difference in the heat treatment given subsequent to forging.

The creep results for the cast-forged comparisons of the same heat of material are best summarized in the flow-time charts of Figs. 23 and 24. Results for 0.20-per-cent carbon steel are quite decisive. At 800° F. (425° C.) the creep curves are quite similar in shape. The small amount of creep (0.05 per cent total) yielded under 10,000 lb. per sq. in. and also the much larger amount (1 per cent total, approximately) under 20,000 lb. per sq. in., both show a slight strength advantage for the forged bars. At 1000° F. (540° C.) an appreciably greater creep resistance is shown by the cast material, particularly at 10,000 lb. per sq. in. where the forged material creeps at over four times the rate attained by the cast.

In the nickel-chromium steel comparison, Fig. 24, the results obtained are not quite as definite as those found for 0.20-per-cent carbon steel and the indications are that the effects of forging on the creep characteristics may not be as marked as for carbon steel. The stresses used at 800° F. (425° C.), 10,000, 20,000 and 30,000 lb. per sq. in. all yielded very little creep. At 10,000 lb. per sq. in., practically no difference appeared. The difference apparent in the 20,000 and 30,000 lb. per sq. in. tests we attribute to eccentricities in material and experiment. At 1000° F. (540° C.) an order of creep coinciding with that found for carbon steel is indicated.

As a general proposition, wrought steels seem to be definitely different in load carrying ability at high temperatures than cast steels of similar composition. While the data given does not afford complete evidence that such is true—probably not as much so as would more tests on identical steels in both conditions—the evidence is in general accord with the observation that small grain size accelerates creep at temperatures above the equi-cohesive temperature. This idea seems quite acceptable at least for low-alloy content steels.

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[1] *Loc. cit.*

The facts supporting the observation are not so apparent from short-time tensile strengths. In fact study of the short-time comparisons given in Figs. 16, 17 and 18 tend even to contradict such an hypothesis. However, turning our attention to the long-time test comparisons afforded by Figs. 2, 3, 4 and 5, it easily can be seen that the treatments represented fall in well-defined groups.

The comparison in Fig. 2 at 800° F. (425° C) 10,000 lb. per sq. in. should be considered representative of small scale creep near the equi-cohesive temperature. Nothing definite can be said in this case for the behavior of cast steel inasmuch as 0.33, 0.20, and 0.40 per cent carbon specimens exhibit a wide range of creep rates. It should be noted that the 0.17, 0.35, 0.41-per-cent carbon wrought steels in the normalized condition form a group lying well above 0.17, 0.20, 0.35-per-cent carbon wrought steel in annealed condition. This is a significant indication that grain size is a greater factor in its effect on creep than is variation in carbon content, considering that the short-time tensile properties for the range 0.17 to 0.41-per-cent carbon vary greatly.

When considering the rather large amount of flow which obtains at 20,000 lb. per sq. in. 800° F. (425° C.) (Fig. 3 left), the results are quite like those shown by short-time tensile strength comparisons. The 0.35 and 0.41-per-cent carbon steels here are seen to offer materially more resistance to creep than the 0.17-per-cent carbon steel. The comparison under these creep conditions will afford a better answer to the question at hand when more tests on wrought materials in the annealed and quenched as well as the normalized condition are completed.

The curves of Fig. 4 for creep tests at 1000° F. (540° C.) under 3000 lb. per sq. in. indicate that small creep rates become increasingly at variance with short-time tension test indications as temperature rises. At this temperature even open-hearth iron shows to advantage among the various carbon steels. The large flow, however, caused by tests under the higher load of 10,000 lb. per sq. in. at 1000° F. (540° C.) (Fig. 5) places these materials in much the same order as do short-time test comparisons.

The creep resistance of rolled steels compared with cast is similar to that of the forged tests discussed above. The difference is probably somewhat greater than found in the comparisons shown here. Whereas the forged specimens were drawn out to only a little more than twice their original length (two-thirds reduction), rolled steel ordinarily undergoes many times this amount of working in passing from ingot to finished bar $\frac{3}{4}$ or 1 in. in diameter. Hence, if working has an effect, a greater divergence in creep characteristics than found between the cast and forged specimen might be expected.

Probably it is to the dendritic structure that the greater creep resistance of cast steel is attributable, acting somehow as a mechanism to inhibit slip. The forged specimen as shown by the photomicrograph (Fig. 22 (*b*)) retained a great deal of its original ingotism. Therefore, quite plausibly, it is held that rolled steels, exhibiting not the slightest vestige of the original dendrites, but instead only small polyhedral grains, in all probability are considerably weaker at high temperatures.

EFFECT OF HEAT TREATMENT ON FLOW

As has been demonstrated previously, large grain size in carbon steels at sufficiently elevated temperatures seems to permit less creep than small grain. That a similar rule holds for other types of steel is indicated by the tests presented in Figs. 25 and 26. A $6\frac{1}{2}$-per-cent tungsten, $6\frac{1}{2}$-per-cent chromium steel with 0.57 per cent carbon (Group No. 159) was selected for the tests shown in Fig. 25 as being representative of alloy steels having good short-time tensile properties at red heats (see Fig. 19 (*c*)). Annealed and tempered structures were produced in the steel as shown by Figs. 22 (*e*) and (*f*), giving the atmospheric tensile properties:

TREATMENT	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	PROPORTIONAL LIMIT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	REDUCTION OF AREA, PER CENT
Annealed at 1675° F. (915° C.)...	125 700	55 000	42 000	16.0	23.0
Oil quenched at 2050° F. (1120° C.), drawn at 1300° F. (705° C.).....	164 000	115 000	87 700	7.0	12.8

For the temperatures 1000, 1200 and 1400° F. (540, 650 and 760° C.) the creep comparisons of Fig. 25 show considerable advantage for annealed over tempered structures, the creep rates being reduced by a very appreciable degree.

As shown in Fig. 26, austenitic steel (Group No. 171) also has its creep characteristics altered by heat treatment. Unlike the non-austenitic steels, the structure resulting from quenching in this case being of larger grain, has increased resistance to creep at red heats, as is brought out by the tests shown in Fig. 26. Despite the fact short-time tests show lower strength in water-quenched material at some temperatures above 1200° F. (650° C.), it is clearly evident that the creep is very substantially reduced. Figures 22 (*c*) and (*d*) illustrate the coarsening of grain that resulted in this steel when heated to 2100° F. (1150° C.) and water quenched.

The creep data with Fig. 22 suggest strongly that at temperatures well above the equi-cohesive temperature, fine-grained structure is less resistant to creep than coarse structure, regardless of whether such structures result from forging, quenching or annealing.

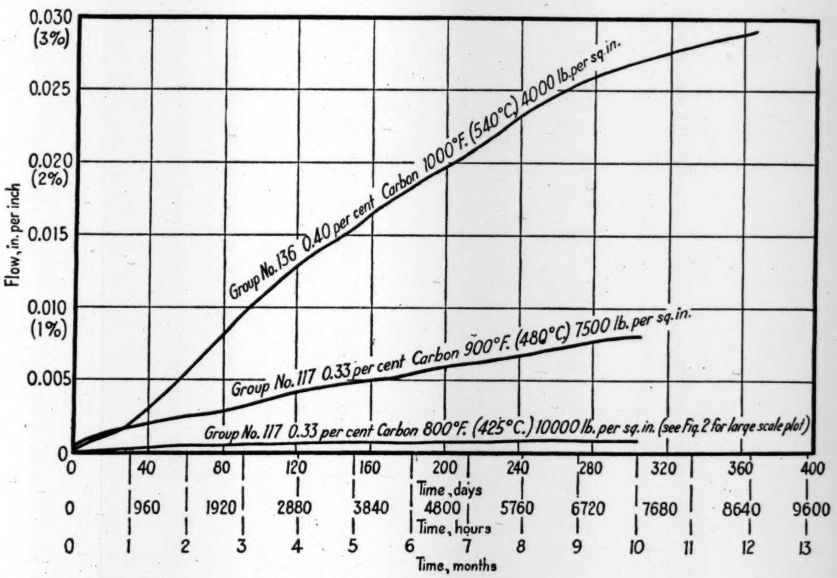

FIG. 1.—Flow-Time Curves for Annealed, Cast Carbon Steels. Tests of 10 and 12 months' duration under constant stress and temperature.

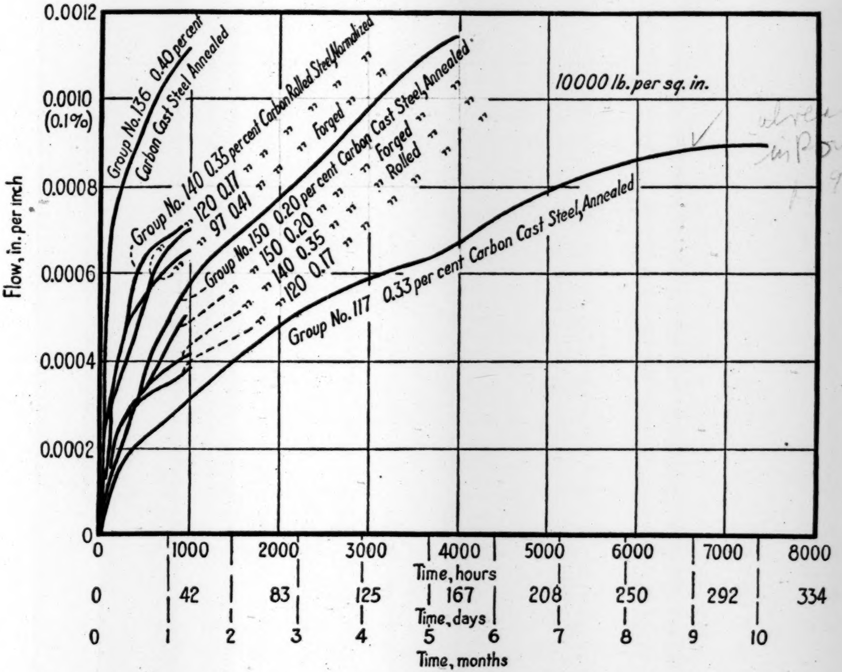

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FIG. 2.—Flow-Time Curves for Several Carbon Steels Under Load of 10,000 lb. per sq. in. at 800° F. (425° C.), Representative of Small-Scale Creep.

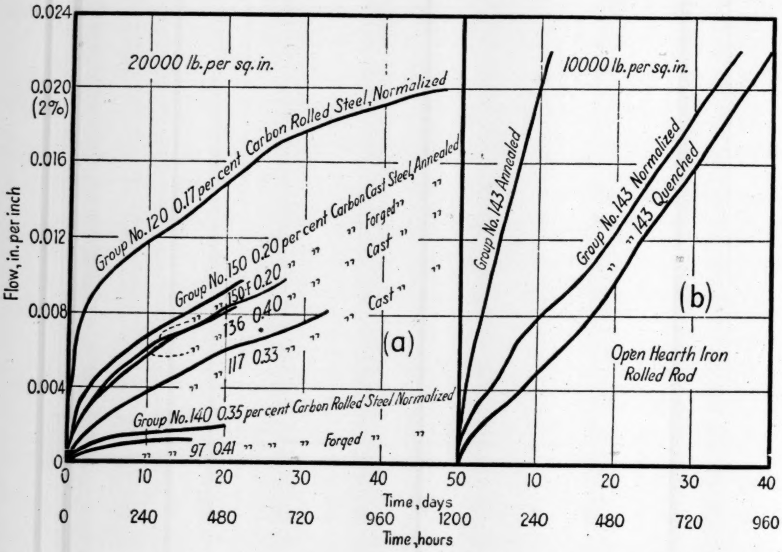


FIG. 3.—Flow-Time Curves for Several Carbon Steels Under Load of 20,000 lb. per sq. in. and Open-Hearth Iron Under Load of 10,000 lb. per sq. in., all at 800° F. (425° C.), Representative of Large-Scale Creep.

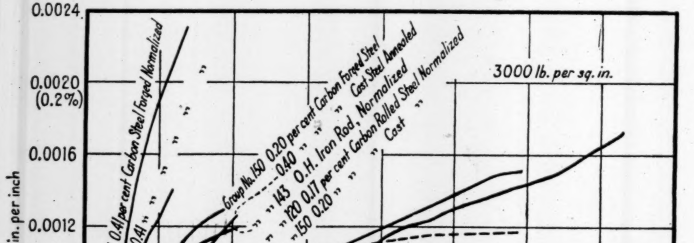


FIG. 4.—Flow-Time Curves for Several Carbon Steels Under Load of 3000 lb. per sq. in. at 1000° F. (540° C.), Representative of Small-Scale Creep.

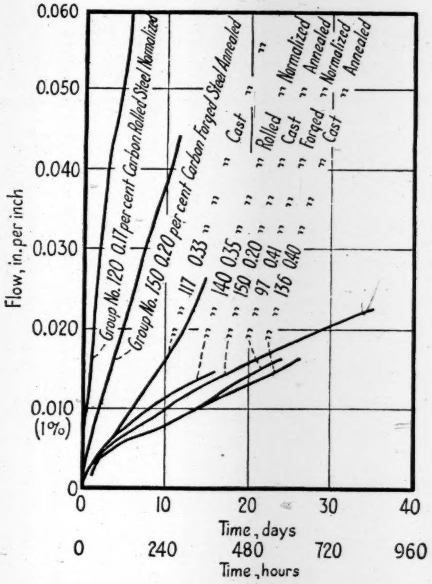


FIG. 5.—Flow-Time Curves for Several Carbon Steels Under Load of 10,000 lb. per sq. in. at 1000° F. (540° C.), Representative of Large-Scale Creep.

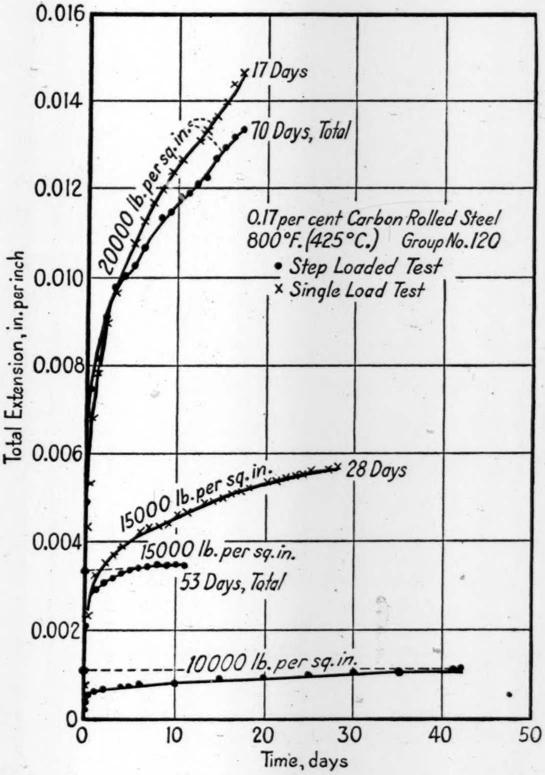


FIG. 6.—Flow-Time Curve for Step-Loaded Specimen Compared with Flow-Time Curves Obtained Using a Separate Specimen for Each Load.

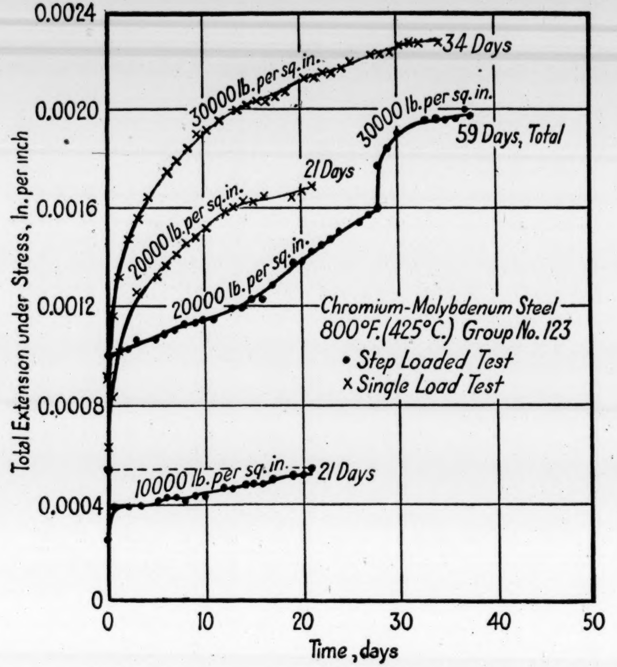


FIG. 7.—Flow-Time Curve for Step-Loaded Specimen Compared with Flow-Time Curves Obtained Using a Separate Specimen for Each Load.

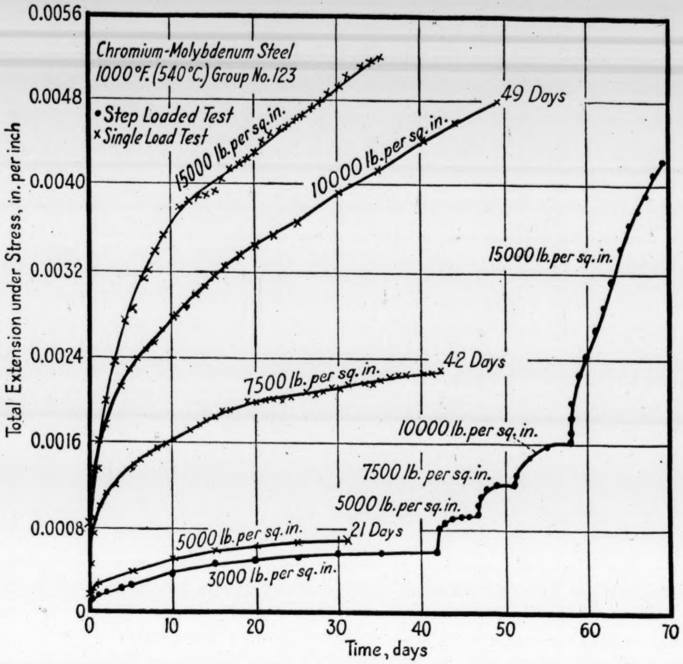


FIG. 8.—Flow-Time Curve for Step-Loaded Specimen Compared with Flow-Time Curves Obtained Using a Separate Specimen for Each Load.

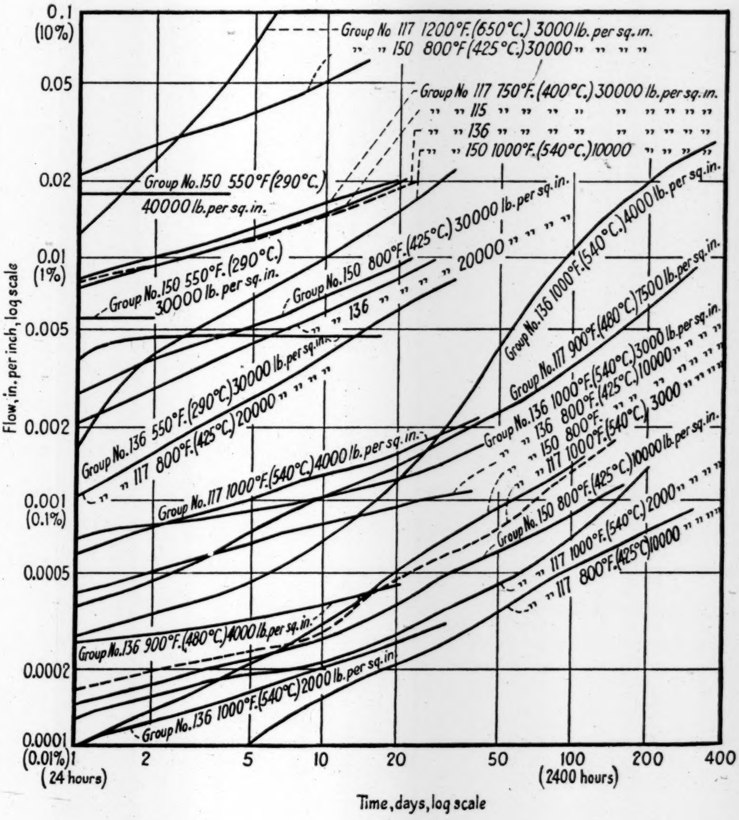


FIG. 9.—Flow-Time Curves for Annealed Carbon Cast Steel, Plotted to Logarithmic Scale.

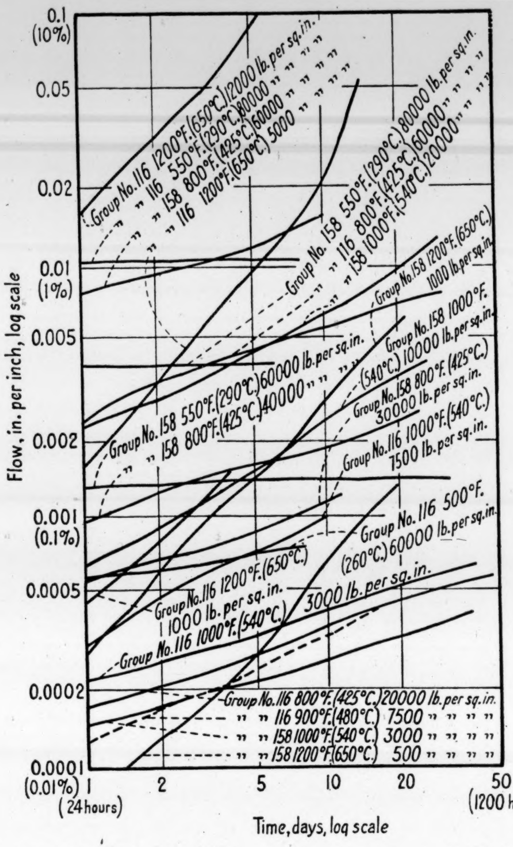


FIG. 10—Flow-Time Curves for Heat-Treated Nickel-Chromium Cast Steel (2 per cent Nickel, 0.85 per cent Chromium, 0.40 per cent Carbon), Plotted to Logarithmic Scale.

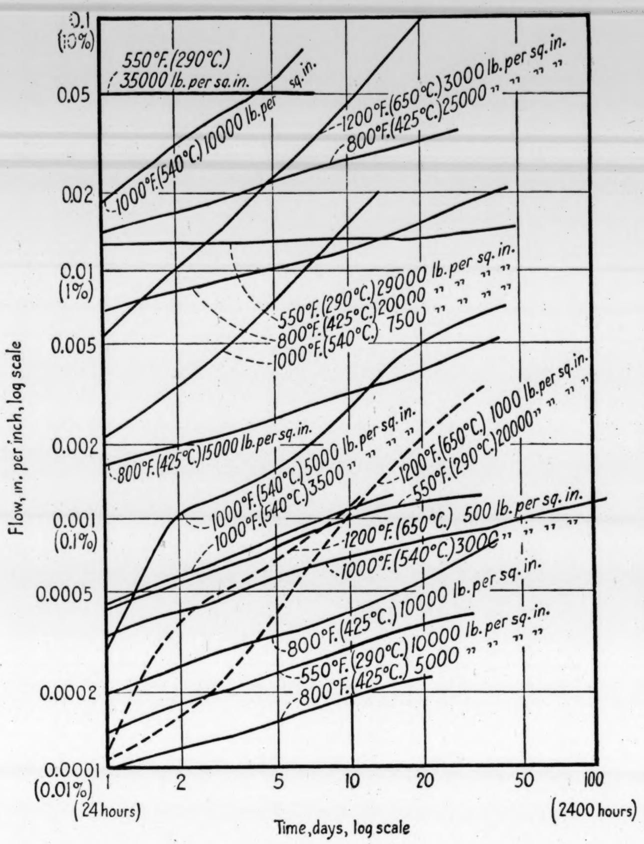


FIG. 11.—Flow-Time Curves for 0.17-per-cent Carbon Open-Hearth Steel Rod Normalized, Plotted to Logarithmic Scale.

cent Chromium, 0.40 per cent Carbon), Plotted to Logarithmic Scale.

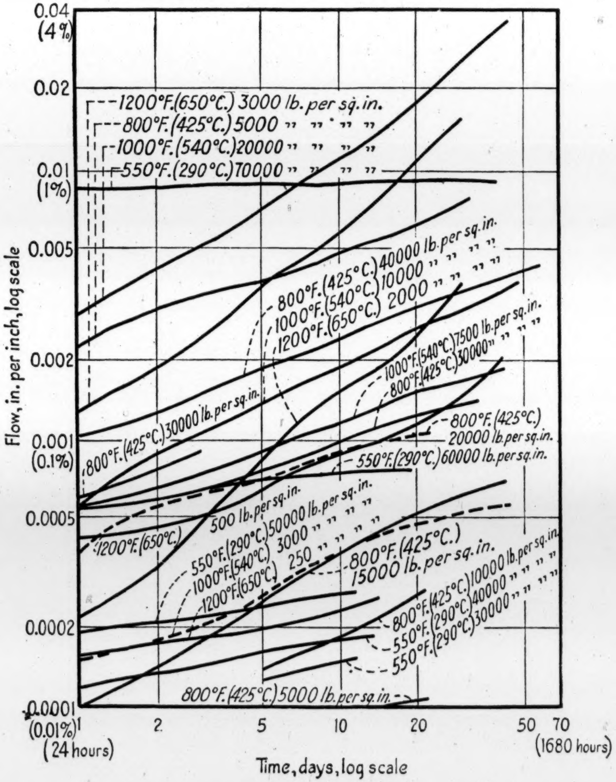


FIG. 12.—Flow-Time Curves for Chromium-Molybdenum Steel Rod, Quenched and Drawn (0.91 per cent Chromium, 0.24 per cent Molybdenum, 0.37 per cent Carbon), Plotted to Logarithmic Scale.

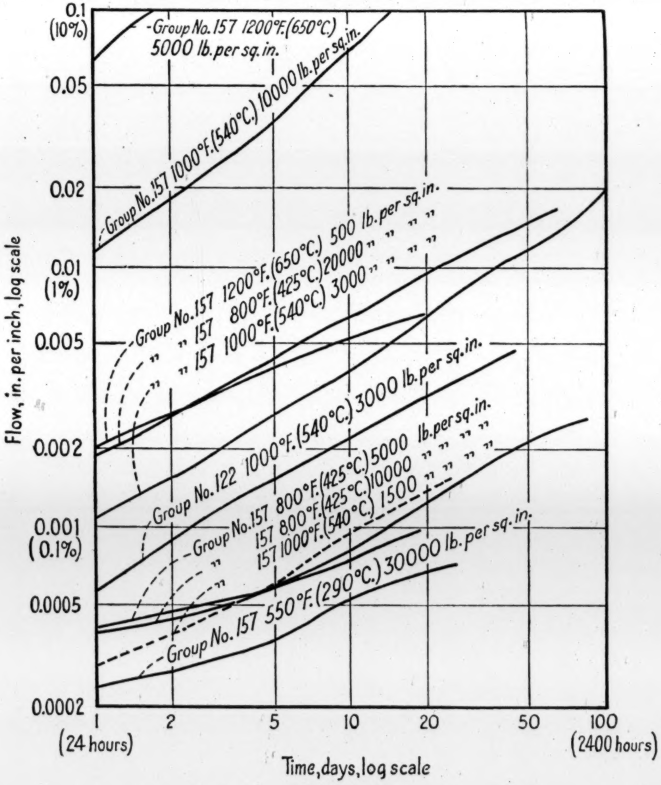


FIG. 13.—Flow-Time Curves for Nickel-Chromium Steel Rod (S.A.E. No. 3140) Quenched and Drawn (1.25 per cent Nickel, 0.6 per cent Chromium, 0.40 per cent Carbon), Plotted to Logarithmic Scale.

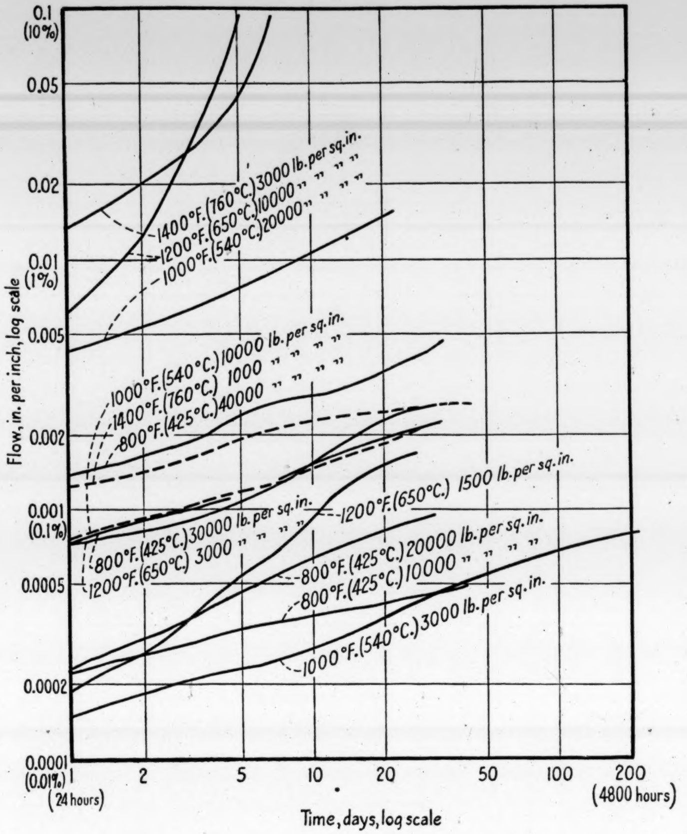


FIG. 14.—Flow-Time Curves for Stainless Iron (12 per cent Chromium, 0.12 per cent Carbon), Air-Quenched and Drawn, Plotted to Logarithmic Scale.

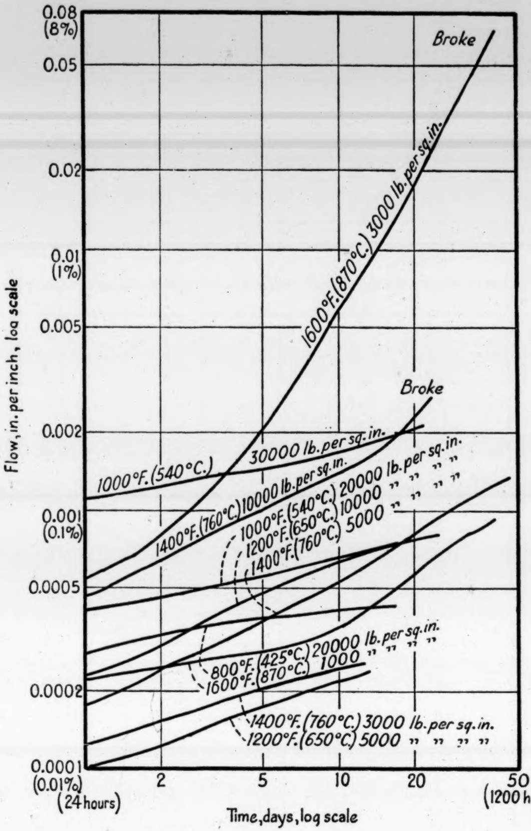


FIG. 15.—Flow-Time Curves for Forged, Austenitic Chromium-Nickel Steel (18 per cent Chromium, 8 per cent Nickel Alloy, 0.10 per cent Carbon), Plotted to Logarithmic Scale.

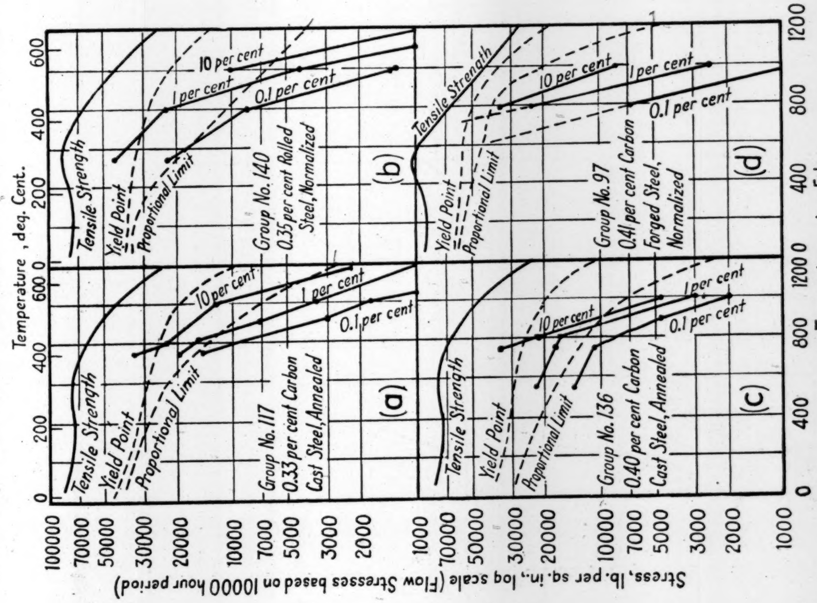


FIG. 16.—Stress-Temperature Curves for Long-Time and Short-Time Tension Tests, Plotted with Logarithmic Stress Ordinate.

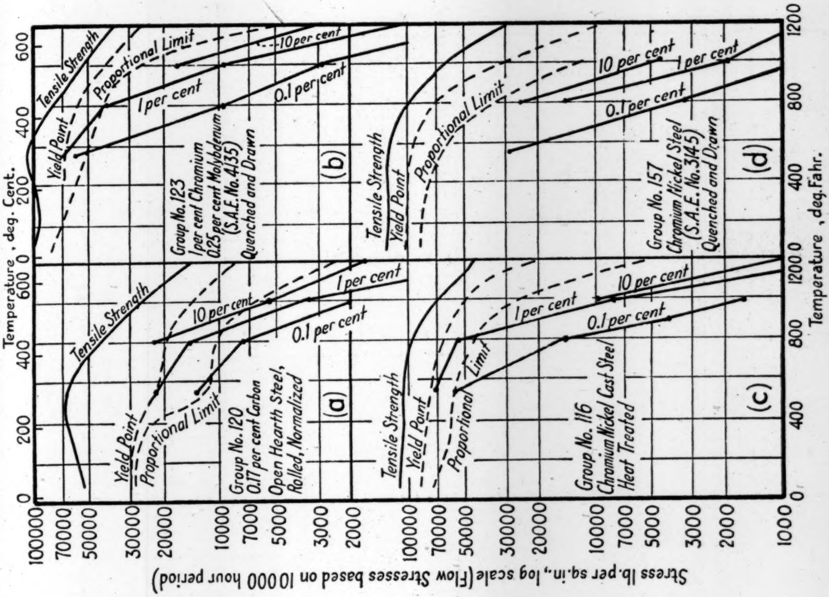


FIG. 17.—Stress-Temperature Curves for Long-Time and Short-Time Tension Tests, Plotted with Logarithmic Stress Ordinate.

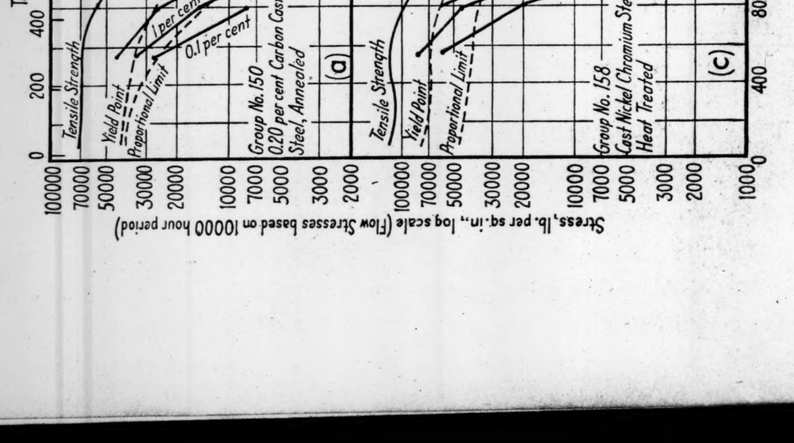


FIG. 18.—Stress-Temperature Curves for Long-Time and Short-Time Tension Tests, Plotted with Logarithmic Stress Ordinate.

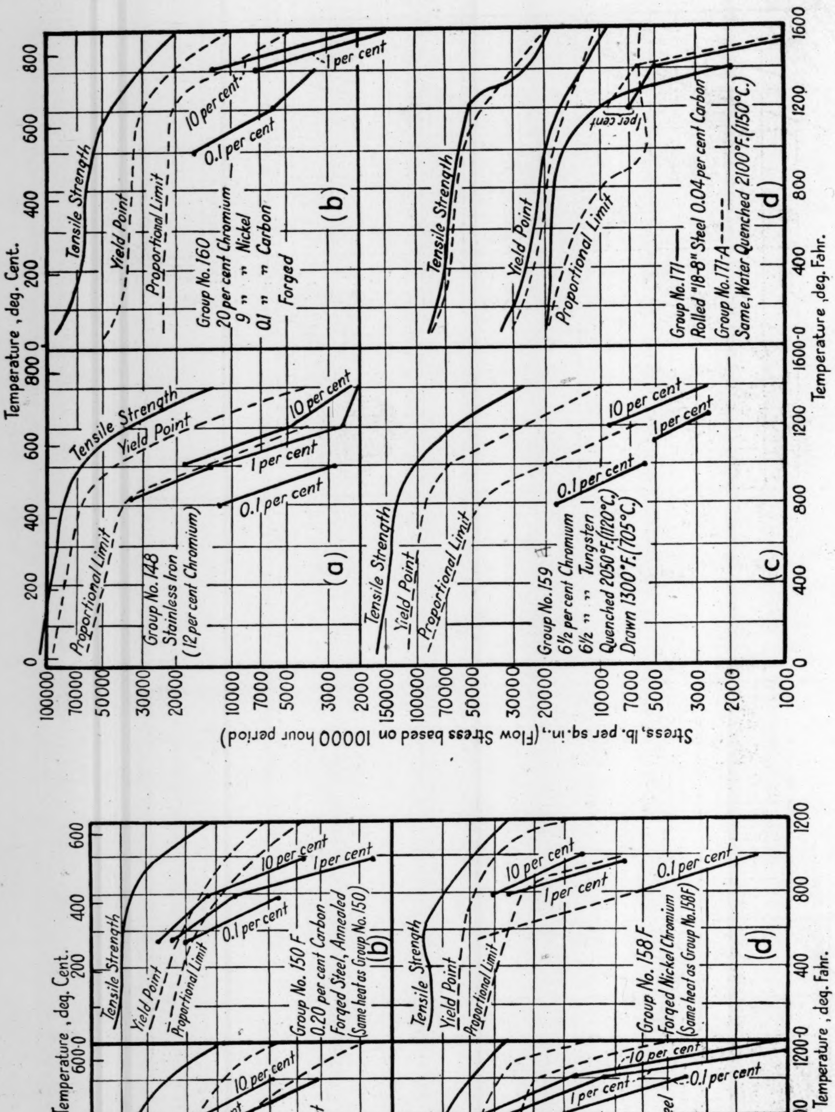


FIG. 19.—Stress-Temperature Curves for Long-Time and Short-Time Tension Tests, Plotted with Logarithmic Stress Ordinate.

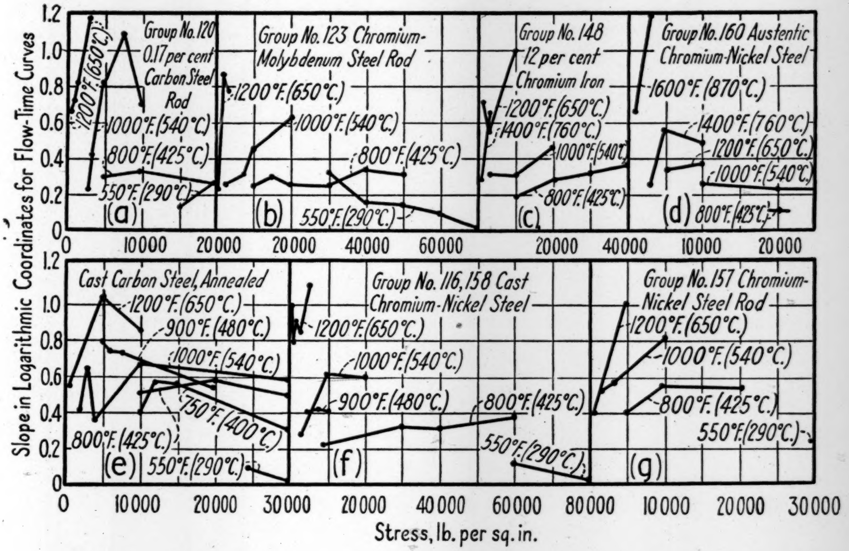


FIG. 20.—Relationship Between Stress and the Slopes of Logarithmic Flow-Time Plots, at Various Temperatures. These diagrams illustrate why limiting creep stress is not a definite constant.

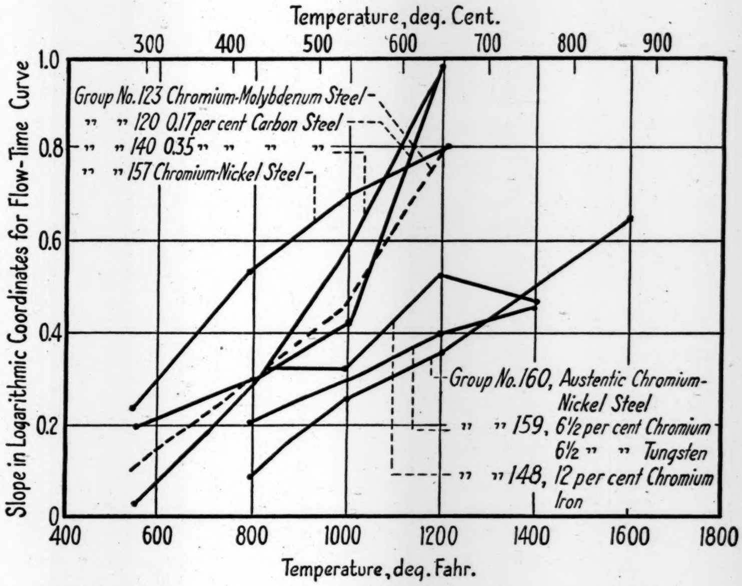
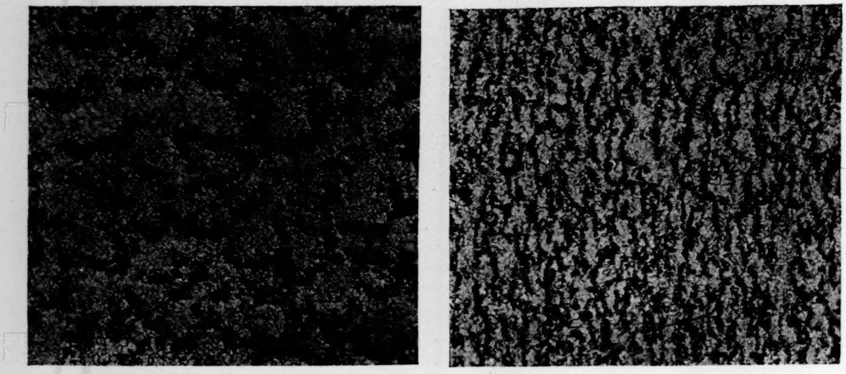
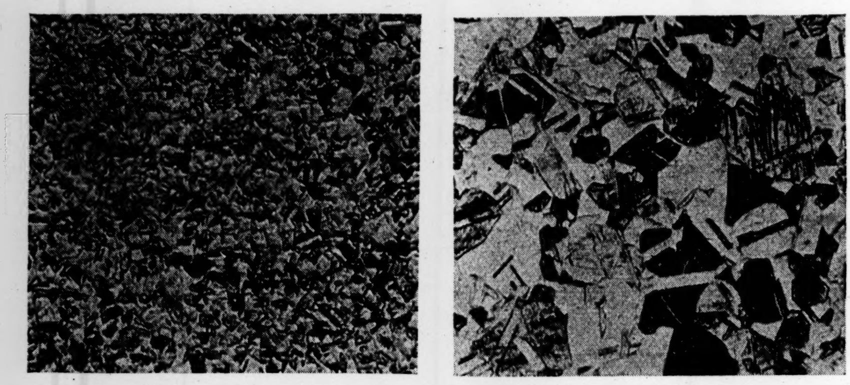


FIG. 21.—Relationship Between Temperature and the Average Slopes of Logarithmic Flow-Time Plots. These diagrams illustrate that the strain-hardening of steels decreases gradually as temperature increases.



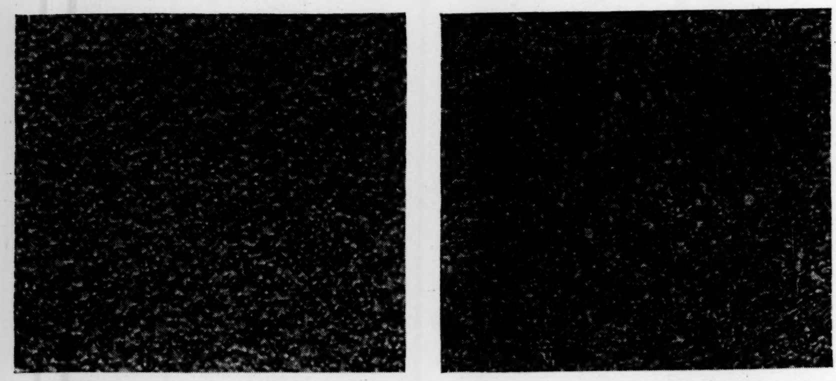
(*a*) Cast, annealed. (*b*) Forged, annealed.

Groups Nos. 150, 150F, 0.20-per-cent carbon steel (× 50). 5-per-cent Nital etch.



(*c*) As rolled. (*d*) Water quenched from 2100° F. (1150° C.).

Groups Nos. 171, 171A, austenitic chromium-nickel steel (18 per cent chromium, 8 per cent nickel) (× 100). Aqua Regia etch.



(*e*) Annealed at 1675° F. (915° C.). (*f*) Oil quenched at 2050° F. (1120° C.), drawn at 1300° F. (705° C.).

Groups Nos. 159, 159A, chromium-tungsten steel ($6\frac{1}{2}$ per cent chromium, $6\frac{1}{2}$ per cent tungsten, 0.57 per cent carbon) (× 1000). 5-per-cent Nital etch.

FIG. 22.—Microstructural Differences Affecting "Creep."

Three different types of steel are represented, with comparatively coarse and fine grain size. The coarser grained material in each case is the more resistant to creep at temperature above the equi-cohesive temperature.

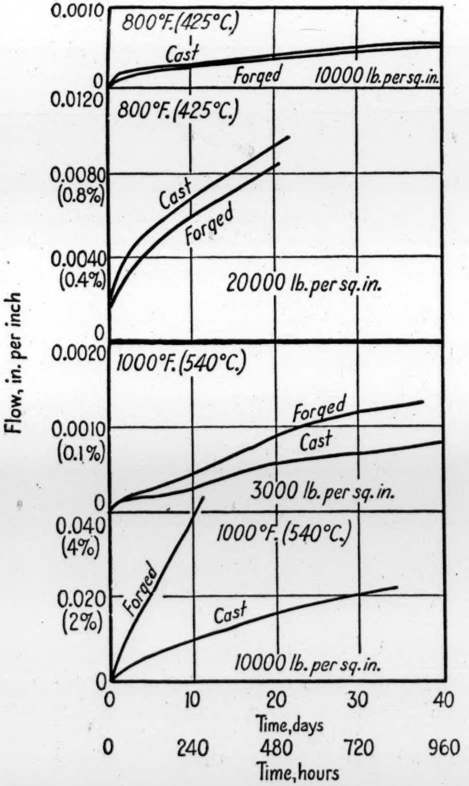


FIG. 23.—Flow-Time Curves for 0.20-per-cent Carbon Steel. Comparison of annealed cast steel with annealed forged steel of identical analysis.

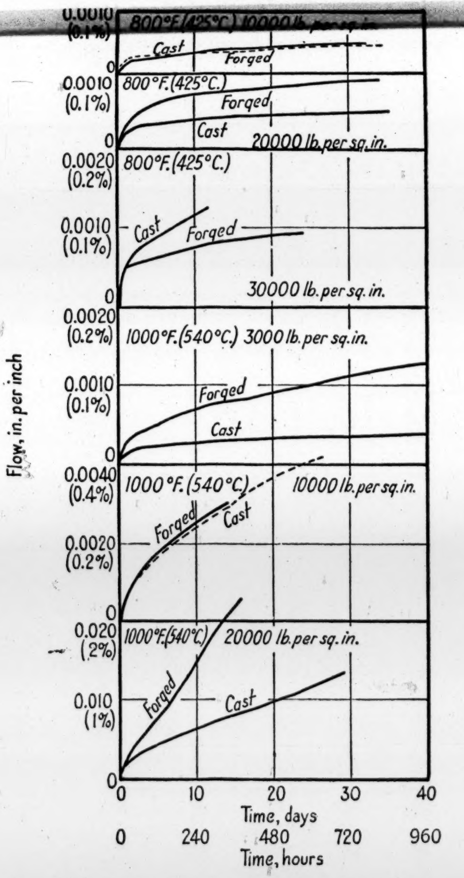


FIG. 24.—Flow-Time Curves for Nickel-Chromium Steel (2 per cent Nickel, 0.87 per cent Chromium, 0.41 per cent Carbon). Comparison of heat-treated alloy cast steel with heat-treated alloy forged steel of identical analysis.

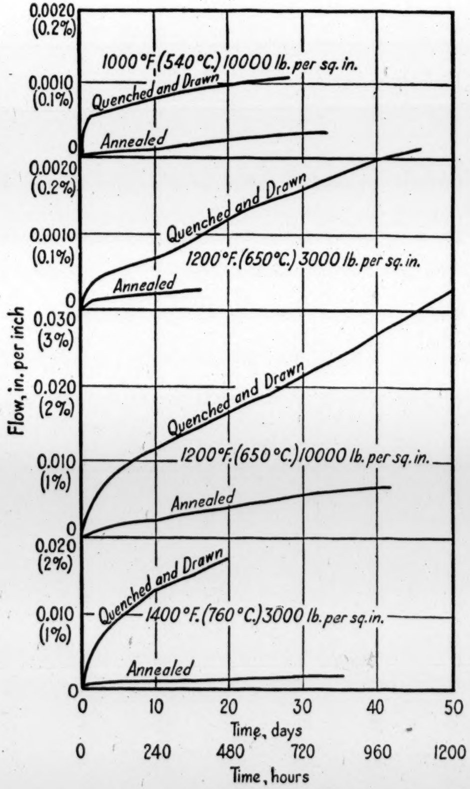


FIG. 25.—Flow-Time Curves for 6½ per cent Tungsten, 6½ per cent Chromium Steel (0.57 per cent Carbon). Comparison of annealed (1675° F. (915° C.)) steel with tempered steel, quenched at 2050° F. (1120° C.), drawn 1300° F. (705° C.).

Short time given | 118

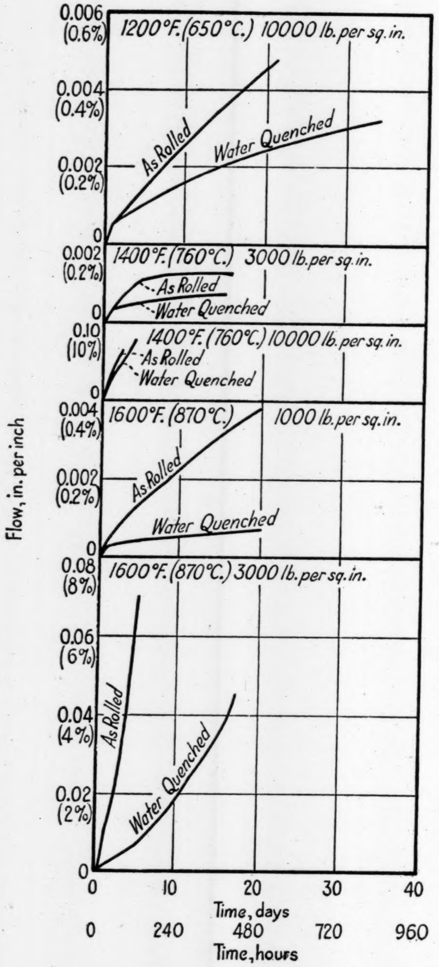


FIG. 26.—Flow-Time Curves for Austenitic Nickel-Chromium Steel (18-8 Alloy, 0.04 per cent Carbon). Comparison of the alloy as rolled and as water quenched from 2100° F. (1150° C.).

REPORT OF RESEARCH COMMITTEE ON YIELD POINT OF STRUCTURAL STEEL

Introduction

Following the program adopted in 1927,[1] the committee has reported three series of tests (No. 261, 271, and 282)[2] dealing mainly with the effect of the speed of movable head on the yield point of structural steel. During the past year a further study of the relationship between the rate of strain in wedge-gripped specimens and the speed of movable head was made in tests of Series No. 291.

In the 200 tests of Series No. 271, besides the information on effect of speed in testing, considerable data were obtained on tensile properties of specimens cut from different parts of structural steel shapes. Additional data on range in yield point, ratio of yield point to ultimate strength and the effect of location of the test specimen were obtained from the 252 tests of Series No. 281. The data from these two series of tests form the basis for this report.

Material

All material for tests of Series No. 271 and 281 was ordered to conform to the Society's Standard Specifications for Structural Steel for Bridges (A 7 – 24). Mill test records and the data on tests of individual specimens of Series No. 271 are recorded in the report of 1928. In that series the specimens were taken from contiguous lengths of light and heavy plates, 6 by 6-in. angles, 15-in. channels, and 24-in. I-beams. Eight heats were represented. To avoid, in so far as possible, the effect of speed variations, only the specimens of that series which were run at yield point with a speed of 0.18 to 0.5 in. per minute are recorded herein.

The specimens for series No. 281 were cut from the shapes indicated in Table I and Fig. 1. Two 5-ft. lengths of each shape were selected from different heats. The selected lengths of girder beams and H-columns had gag lines running transverse to their axes at mid-length. Each of these 5-ft. lengths was cut transversely to make three portions, each 18 in. long. From the mid-portions of these 5-ft. lengths the "gagged" specimens of this series were cut. The normal specimens and specimens for annealing were taken from contiguous portions. No specimens for annealing were taken from the H-columns. The 5-ft. lengths of plates and angles were so cut that their mid-portions had rested directly on the skids during cooling. From these mid-portions were taken the "skid" specimens. The

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[1] Progress Report of Research Committee on Yield Point of Structural Steel, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 646 (1927).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 105 (1928); and Vol. 29, Part I, p. 101 (1929).

TABLE I.—MILL TESTS ON PHYSICAL PROPERTIES AND CHEMICAL ANALYSES OF SPECIMENS—SERIES NO. 281.

	Chemical Analysis[a]				Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Pulling Speed, in. per minute		Elongation in 8 in., per cent	Heat Number
	Carbon, per cent	Manganese, per cent	Phosphorus, per cent	Sulfur, per cent			Yield Point	Tensile Strength		
PLATES:										
12 by $\frac{3}{8}$ in.....	0.16	0.43	0.012	0.043	58 300	36 970	[b]	[c]	30.50	25 602
15 by $\frac{3}{8}$ in.....	0.15	0.37	0.014	0.028	56 800	35 610	[b]	[c]	30.00	16 636
13$\frac{1}{2}$ by $\frac{7}{8}$ in....	0.14	0.39	0.010	0.030	55 820	35 270	[b]	[c]	28.00	19 603
14 by $\frac{7}{8}$ in.....	0.19	0.42	0.011	0.055	57 400	32 550	[b]	[c]	28.00	21 664
ANGLES:										
8 by 8 by $\frac{1}{2}$ in..	0.16	0.42	0.011	0.028	57 990	34 970	[b]	[c]	32.50	24 571
8 by 8 by $\frac{1}{2}$ in..	0.17	0.40	0.013	0.029	58 540	35 600	[b]	[c]	29.75	920 365
8 by 8 by 1 in..	0.29	0.45	0.012	0.038	64 180	40 880	[b]	[c]	26.25	22 591
8 by 8 by 1 in..	0.24	0.44	0.012	0.026	62 810	40 140	[b]	[c]	29.50	18 416
GIRDER BEAM:										
24 in. 70 lb....	0.15	0.44	0.018	0.028	58 040	37 710	[b]	[c]	29.50	21 676
24 in. 70 lb....	0.20	0.53	0.021	0.032	63 170	36 120	[b]	[c]	27.75	24 631
26 in. 160 lb....	0.13	0.56	0.015	0.045	60 700	40 170	[d]	[e]	31.20	41J 002
26 in. 160 lb....	0.14	0.73	0.016	0.040	64 500	43 900	[d]	[e]	31.20	32J 002
H-COLUMN:										
14 in. 288 lb....	0.14	0.64	0.015	0.038	63 300	38 400	[d]	[e]	28.70	32H 532
14 in. 288 lb....	0.20	0.64	0.010	0.041	62 640	34 360	[d]	[e]	27.50	41H 454
14 in. 84 lb.....	0.15	0.60	0.012	0.042	65 000	43 650	[d]	[e]	28.70	31H 606
14 in. 84 lb.....	0.22	0.69	0.010	0.035	64 200	43 920	[d]	[e]	26.20	43H 539

[a] Values are check analysis.
[b] Speed of head of testing machine at yield point $\frac{1}{2}$ in. per minute.
[c] Speed of head of testing machine at tensile strength 7.06 in. per minute.
[d] Speed of head of testing machine at yield point $\frac{1}{4}$ in. per minute.
[e] Speed of head of testing machine at tensile strength 1 in. per minute.

TABLE II.—MACHINES USED AND SHAPES TESTED AT COOPERATING LABORATORIES SERIES NO. 281.

Laboratory	Machine	Speed of Head of Testing Machine, in. per minute		Shapes Tested	Number of Specimens Tested
		Yield Point	Tensile Strength		
1. University of Wisconsin..	Riehle 3-screw, 200,000-lb.....	0.06	1.25	H-Columns	72
2. Rensselaer Polytechnic Inst................	Olsen 3-screw, 60,000-lb....... Riehle 2-screw, 150,000-lb.....	0.05	1.0	Girder Beams	108
5. Bethlehem Steel Co., Coatesville Plant......	Olsen 4-screw, 100,000-lb.....	0.50	1.12	Angles and Plates	72

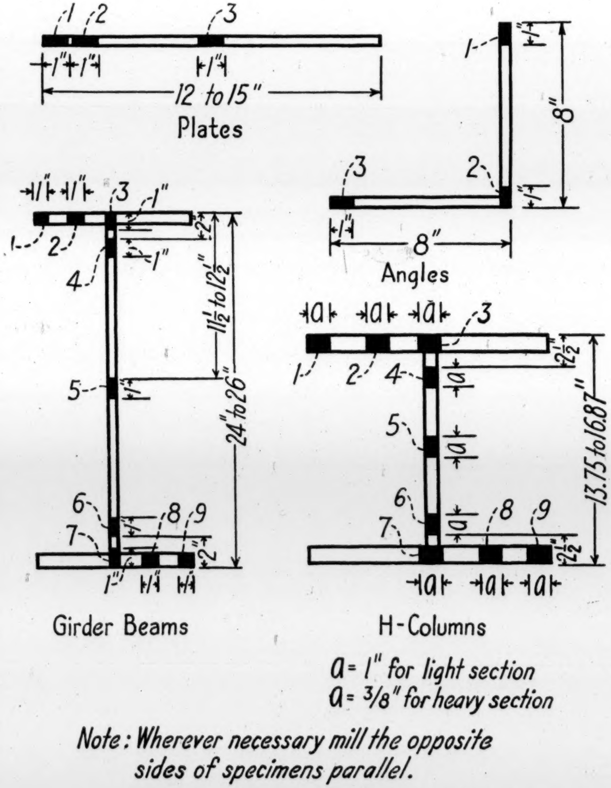
1
2
3
1"
1"
1"
12 to 15"
Plates
1
2
3
8"
1"
1"
8"
Angles
1"
1"
3
1"
1
2
4
1"
$11\frac{1}{2}$ to $12\frac{1}{2}$"
2"
5
1"
24" to 26"
6
7
8
9
2"
1"
1"
1"
Girder Beams
a
a
a
3
1
2
4
a
5
a
6
a
7
8
9
$2\frac{1}{2}$"
$2\frac{1}{2}$"
13.75 to 16.87"
a
a
a
H-Columns
a = 1" for light section
a = 3/8" for heavy section
Note: Wherever necessary mill the opposite sides of specimens parallel.

FIG. 1.—Position of Specimens in Structural Shapes—Series No. 281.

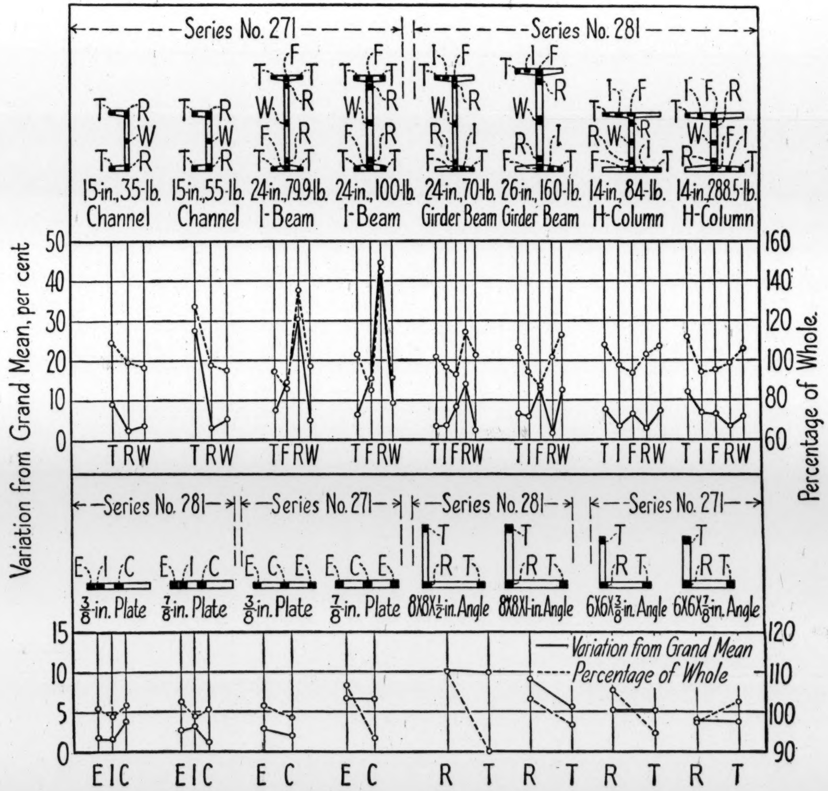

FIG. 2.—The Variations in Yield Point of Specimens from Different Locations in Shapes and the Ratio of Their Yield Points to Weighted Mean Yield Point for the Whole Shape.

normal specimens and specimens for annealing from these shapes were taken from portions contiguous to the skid specimens.

The location of and the cross-sectional dimensions of the specimens taken from the different shapes is shown in Fig. 1.

TABLE III.—COMPARISON OF STRENGTH VALUES OF NORMAL SPECIMENS WITH SIMILAR VALUES FOR SKID OR GAGGED SPECIMENS—SERIES NO. 281.

Shape	Location of Specimen	Number of Each Type of Specimen	Average Yield Point, Drop-of-Beam Method, lb. per sq. in.		Average Tensile Strength, lb. per sq. in.		Ratios	
							Yield Point	Tensile Strength
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
			Skid Specimens	Normal Specimens	Skid Specimens	Normal Specimens	Ratio, Skid Specimens to Normal Specimens	
$\frac{3}{8}$-in. Plate.........	Edge.........	2	33 505	34 515	53 645	53 475	0.971	1.004
	Intermediate..	2	32 830	33 630	53 515	53 460	0.977	1.002
	Center........	2	33 375	35 095	55 830	55 910	0.952	0.999
$\frac{7}{8}$-in. Plate.......	Edge.........	2	31 810	31 430	54 470	54 540	1.013	0.999
	Intermediate..	2	30 505	30 635	54 730	54 700	0.996	1.000
	Center.......	2	30 960	31 195	56 120	56 030	0.993	1.002
8 by 8 by $\frac{1}{2}$-in. Angle	Toe..........	4	34 150	34 070	56 410	57 430	1.003	0.983
	Root.........	2	40 505	42 800	61 850	61 390	0.947	1.008
8 by 8 by 1-in. Angle	Toe..........	4	37 180	33 360	57 270	56 430	1.114	1.014
	Root.........	2	39 370	35 820	63 890	62 660	1.098	1.020
Mean..............	....	....	34 630	34 165	56 785	56 660	.....	.....
			Gagged Specimens	Normal Specimens	Gagged Specimens	Normal Specimens	Ratio, Gagged Specimens to Normal Specimens	
24-in., 70-lb. Girder Beam...........	Toe..........	4	32 175	31 950	57 045	56 130	1.007	1.017
	Intermediate..	4	30 170	30 535	56 880	58 390	0.988	0.975
	Mid-Flange...	4	28 905	29 830	56 540	55 430	0.970	1.020
	Root.........	4	35 865	36 010	57 685	58 780	0.996	0.972
	Web..........	2	32 425	32 075	56 620	56 925	1.012	0.996
26-in., 160-lb. Girder Beam...........	Toe..........	4	33 415	34 360	55 365	55 860	1.002	0.991
	Intermediate..	4	30 490	29 320	55 330	55 040	1.040	1.005
	Mid-Flange...	4	28 025	27 275	55 570	55 305	1.028	1.004
	Root.........	4	32 410	32 250	57 000	56 595	1.006	1.008
	Web..........	2	36 260	35 440	58 375	57 970	1.023	1.007
14-in., 84-ln. H-Column.........	Toe..........	4	37 685	38 055	59 900	59 630	0.990	1.004
	Intermediate..	4	34 420	34 180	59 120	58 755	1.007	1.007
	Mid-Flange...	4	32 855	33 020	58 145	58 610	0.996	0.992
	Root.........	4	36 100	36 240	59 890	61 015	0.997	0.972
	Web..........	2	37 475	37 875	59 800	60 440	0.989	0.990
14-in., 288.5-lb. H-Column.........	Toe..........	4	34 835	34 950	58 845	58 885	0.997	0.999
	Intermediate..	4	29 820	28 730	55 620	57 850	1.038	0.962
	Mid-Flange...	4	29 455	29 640	55 940	56 790	0.994	0.985
	Root.........	4	31 310	29 940	57 240	57 150	1.047	1.002
	Web..........	2	32 960	32 955	57 860	58 310	1.000	0.992
Mean..............	....	....	32 640	32 525	57 360	57 610	.....	.....

NOTE.—In yield point, the normal specimens were higher than the skid in 14 of the 24 comparisons made.
In tensile strength, the normal specimens were higher than the skid in 8 of the 24 comparisons made.
In yield point, the normal specimens were higher than the gagged in 32 of the 72 comparisons made.
In tensile strength, the normal specimens were higher than the gagged in 41 of the 72 comparisons made.

The specimens of Series No. 271 and those from the plates, angles, and 70-lb. girder beam of Series No. 281 were prepared under the direction of Mr. F. S. Crane and donated by the Illinois Steel Co. The specimens from the 160-lb. girder beam and the H-columns were prepared under the direction of Mr. E. F. Kenney and donated by the Bethlehem Steel Co.

The tabulations made herein are based upon tests of 372 specimens from 68 portions of shapes. Eight shapes, each in two weights, and 24 heats are represented.

The cooperating laboratories, machines and speeds used, and the shapes tested are listed in Table II.

TABLE IV.—WEIGHTS ASSIGNED TO SPECIMENS IN DETERMINING MEAN VALUES.

Series No. 281			Series No. 271		
Shape	Position of Specimen in Shape	Weight, per cent	Shape	Position of Specimen in Shape	Weight, per cent
12 by $\frac{3}{8}$-in. Plate	Edge	17	All Plates	Edge	50
	Intermediate	46		Center	50
	Middle	37	All Angles	Toe	50
15 by $\frac{3}{8}$-in. Plate	Edge	13		Root	50
	Intermediate	47	15-in., 33-lb. Channel	Toe	22
	Middle	40		Root	38
14 by $\frac{7}{8}$-in. Plate	Edge	15		Web	40
	Intermediate	46	15-in., 55-lb. Channel	Toe	13
	Middle	39		Root	36
All Angles	Toe	50		Web	51
	Root	50	24-in., 79. 9-lb. I-beam	Toe	27
24-in., 70-lb. Girder Beam	Toe	17		Flange	26
	Intermediate	24		Root	12
	Mid-Flange	18		Web	35
	Root	8	24-in., 100-lb. I-beam	Toe	22
	Web	33		Flange	23
26-in., 160-lb. Girder Beam	Toe	15		Root	14
	Intermediate	31		Web	41
	Mid-Flange	21			
	Root	6			
	Web	27			
14-in., 84-lb. H-Column	Toe	21			
	Intermediate	36			
	Mid-Flange	25			
	Root	9			
	Web	9			
14- in , 288-lb. H-Column	Toe	20			
	Intermediate	39			
	Mid-Flange	20			
	Root	3			
	Web	18			

METHOD OF TESTING

The screw-gear-driven lever machines were all in good condition at the time the tests of Series No. 281 were made. Specimens were gripped with serrated wedges and loaded with a controllable speed to three-fourths of the estimated yield point. The speed indicated in Table II was then used until the yield point had been determined by drop of beam, by dividers, and by scaling. The remainder of the test was run at the speed indicated in Table II. The reported values of yield point are based on drop-of-beam indications excepting two specimens where no drop of beam occurred. In those cases, the divider indication was substituted.

TABLE V.—MINIMUM AND MEAN VALUES OF YIELD POINTS IN TENSION OF SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NOS. 271 AND 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Yield Point, Drop-of-Beam Method				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	2	3	4	5	6	7	8	9
$\frac{3}{8}$-in. Plate, Series 281	0.5	Edge.........	4	32 970	34 010	100.6	1.4	1.7
	0.5	Intermediate..	4	32 150	33 230	98.6	0.8	1.5
	0.5	Center........	4	32 880	34 235	101.6	4.1	3.7
	...	Whole........	..	.....	33 700	.....	...	...
$\frac{7}{8}$-in. Plate, Series 281	0.5	Edge.........	4	30 650	31 620	102.2	1.4	2.7
	0.5	Intermediate..	4	29 450	30 570	98.8	3.1	3.1
	0.5	Center........	4	30 730	31 080	100.5	1.7	1.1
	...	Whole........	..	.....	30 930	.....	...	...
$\frac{3}{8}$-in. Plate, Series 271	0.5 – 0.18	Edge.........	6	35 080	36 415	101.5	2.4	2.9
	0.5 – 0.18	Center........	3	34 700	35 360	98.5	1.5	2.0
	....	Whole........	..	.....	35 890	.....	...	...
$\frac{7}{8}$-in. Plate, Series 271	0.5 – 0.18	Edge.........	6	31 740	32 510	106.7	1.5	6.7
	0.5 – 0.18	Center........	3	27 235	28 460	93.3	3.2	6.6
	....	Whole........	..	.....	30 485	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle, Series 281.........	0.5	Toe..........	8	30 600	34 110	90.0	4.0	9.9
	0.5	Root.........	4	37 910	41 650	110.0	8.2	10.2
	...	Whole........	..	.....	37 880	.....	...	...
8 by 8 by 1-in. Angle, Series 281.........	0.5	Toe..........	8	30 760	35 270	96.9	5.4	5.6
	0.5	Root.........	4	32 100	37 595	103.1	7.3	9.1
	...	Whole........	..	.....	36 430	.....	...	...
6 by 6 by $\frac{3}{8}$-in. Angle, Series 271.........	0.5 – 0.18	Toe..........	6	37 065	37 805	94.8	1.1	5.2
	0.5 – 0.18	Root.........	3	40 960	41 935	105.2	1.5	5.2
	....	Whole........	..	.....	39 870	.....	...	...
6 by 6 by $\frac{7}{8}$-in. Angle, Series 271.........	0.5 – 0.18	Toe..........	6	29 750	31 850	102.6	3.3	3.8
	0.5 – 0.18	Root.........	3	29 000	30 255	97.4	4.2	4.0
	....	Whole........	..	.....	31 050	.....	...	...
15-in., 35-lb. Channel, Series 271.........	0.5 – 0.18	Toe..........	6	37 620	39 030	109.0	2.3	9.0
	0.5 – 0.18	Root.........	6	33 915	35 360	98.8	2.5	2.5
	0.5 – 0.18	Web..........	3	33 510	34 460	96.2	2.3	3.7
	....	Whole........	..	.....	35 740	.....	...	...
15-in., 55-lb. Channel, Series 271.........	0.5 – 0.18	Toe..........	6	38 790	40 595	127.3	2.5	27.3
	0.5 – 0.18	Root.........	6	30 160	31 060	97.4	1.4	3.0
	0.5 – 0.18	Web..........	3	29 090	30 250	94.9	2.7	5.1
	....	Whole........	..	.....	31 890	.....	...	...
24-in., 79.9-lb. I-Beam' Series 271.........	0.5 – 0.18	Toe..........	12	28 715	33 185	94.2	5.3	7.4
	0.5 – 0.18	Flange........	6	27 280	30 120	85.6	5.8	14.4
	0.5 – 0.18	Root.........	6	42 840	46 370	135.3	6.1	30.4
	0.5 – 0.18	Web..........	3	31 540	34 130	97.0	5.1	4.9
	....	Whole........	..	.....	34 290	.....	...	...
24-in., 100-lb. I-Beam, Series 271.........	0.5 – 0.18	Toe..........	12	30 630	34 955	103.3	5.5	6.2
	0.5 – 0.18	Flange........	6	27 970	28 620	84.6	1.3	15.4
	0.5 – 0.18	Root.........	6	42 000	48 615	144.4	10.6	44.6
	0.5 – 0.18	Web..........	3	30 080	30 745	90.9	2.1	9.1
	....	Whole........	..	.....	33 690	.....	...	...
24-in., 70-lb. Girder Beam, Series 281...	0.05	Toe..........	8	30 260	32 060	101.6	3.3	3.5
	0.05	Intermediate..	8	29 120	30 350	96.2	1.7	3.7
	0.05	Mid-Flange...	8	27 490	29 370	93.1	5.4	8.1
	0.05	Root.........	8	31 300	35 940	114.0	6.5	14.0
	0.05	Web..........	4	31 400	32 250	102.3	2.0	2.3
	....	Whole........	..	.....	31 530	.....	...	...

TABLE V.—*Continued.*

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Yield Point, Drop-of-Beam Method				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
26-in., 160-lb. Girder Beam, Series 281 ..	0.05	Toe..........	8	32 380	33 890	106.7	2.3	6.7
	0.05	Intermediate..	8	28 730	29 905	94.1	2.9	5.9
	0.05	Mid-Flange...	8	26 370	27 650	87.0	2.8	13.0
	0.05	Root.........	8	31 625	32 330	101.7	1.8	1.7
	0.05	Web..........	4	35 390	35 850	112.9	1.4	12.8
	....	Whole........	..	.....	31 775	.....	...	...
14-in., 84-lb. H-Column, Series 281.	0.06	Toe..........	8	36 480	37 870	107.6	2.7	7.7
	0.06	Intermediate..	8	32 550	34 300	97.6	2.5	3.3
	0.06	Mid-Flange...	8	31 660	32 940	93.7	1.2	6.3
	0.06	Root.........	8	35 450	36 170	102.8	1.9	2.9
	0.06	Web..........	4	36 680	37 675	107.1	2.2	7.2
	....	Whole........	..	.....	35 160	.....	...	...
14-in., 288.5-lb. H-Column, Series 281.	0.06	Toe..........	8	33 510	34 890	112.0	1.8	12.0
	0.06	Intermediate..	8	27 800	29 270	93.9	4.5	6.9
	0.06	Mid-Flange...	8	25 960	29 550	94.8	5.2	6.4
	0.06	Root.........	8	28 230	30 630	98.3	3.2	3.3
	0.06	Web..........	4	31 980	32 960	105.8	1.9	5.8
	....	Whole........	..	.....	31 160	.....	...	...

Normal versus Gagged or Skid Specimens:

The average yield points and tensile strengths for the normal, gagged, and skid specimens of Series No. 281 are given in Table III. These data indicate that the tensile strength was affected little if at all by gagging or proximity of the cooling skids. The yield points of the gagged specimens were slightly higher than those of the normal specimens in 40 out of 72 comparisons. The yield points of skid and normal specimens from angles were approximately the same. Yield points for skid specimens of the 8 by 8 by 1-in. angle specimens were about ten per cent higher than for the corresponding normal specimens. Chemical analysis of the fractured specimens failed to disclose a reason for this difference.

Since in most cases the effects of gagging and cooling skids were small, the values for gagged, skid and normal specimens have been averaged together in subsequent tables.

Method of Weighting Test Data:

In order to arrive at values of the various tensile properties which would best represent the portion of a given shape, weights were assigned to the individual specimen test values in accordance with the percentages listed in Table IV. These percentage weightings are based on the portion of the cross-sectional area of the shape repre-

TABLE VI.—MINIMUM AND MEAN TENSILE STRENGTHS OF SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NOS. 271 AND 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Tensile Strength				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
$\frac{3}{8}$-in. Plate, Series 281	0.5	Edge	4	52 570	53 560	98.4	1.8	1.8
	0.5	Intermediate	4	52 520	53 490	98.3	1.7	1.7
	0.5	Center	4	54 600	55 870	102.7	2.0	2.7
	0.5	Whole	..	.....	54 400	.....	...	...
$\frac{7}{8}$-in. Plate, Series 281	0.5	Edge	4	53 740	54 505	98.7	1.3	1.4
	0.5	Intermediate	4	53 500	54 715	99.1	2.1	2.1
	0.5	Center	4	55 860	56 075	101.6	0.2	1.6
	...	Whole	..	.....	55 210	.....	...	...
12 by $\frac{3}{8}$-in. Plate, Series 271	0.18 – 0.5	Edge	6	58 070	58 860	100.4	0.7	0.7
	0.18 – 0.5	Center	3	57 980	58 460	99.7	0.6	0.7
	....	Whole	..	.....	58 660	.....	...	...
12 by $\frac{7}{8}$-in. Plate, Series 271	0.18 – 0.5	Edge	6	60 810	61 550	102.4	0.8	2.4
	0.18 – 0.5	Center	3	58 375	58 660	97.7	0.6	2.4
	....	Whole	..	.....	60 105	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle, Series 281	0.5	Toe	8	55 200	56 920	96.0	2.5	4.8
	0.5	Root	4	59 740	61 620	104.0	2.9	4.0
	...	Whole	..	.....	59 260	.....	...	...
8 by 8 by 1-in. Angle, Series 281	0.5	Toe	8	53 220	56 850	94.7	6.0	6.1
	0.5	Root	4	60 520	63 275	105.3	2.7	5.4
	...	Whole	..	.....	60 060	.....	...	...
6 by 6 by $\frac{3}{8}$-in. Angle, Series 271	0.18 – 0.5	Toe	6	58 660	59 305	97.5	0.7	2.4
	0.18 – 0.5	Root	3	61 260	62 265	102.5	1.3	2.4
	....	Whole	..	.....	60 785	.....	...	...
6 by 6 by $\frac{7}{8}$-in. Angle, Series 271	0.18 – 0.5	Toe	6	55 220	55 825	101.2	0.9	1.2
	0.18 – 0.5	Root	3	53 920	54 535	98.8	1.3	1.6
	....	Whole	..	.....	55 180	.....	...	...
15-in., 35-lb. Channel, Series 271	0.18 – 0.5	Toe	6	54 920	55 770	103.2	1.3	3.3
	0.18 – 0.5	Root	6	52 240	52 960	98.1	0.8	1.9
	0.18 – 0.5	Web	3	53 330	54 115	100.2	1.0	1.1
	....	Whole	..	.....	54 010	.....	...	...
15-in., 55-lb. Channel, Series 271	0.18 – 0.5	Toe	6	58 140	59 665	105.7	1.5	5.7
	0.18 – 0.5	Root	6	55 005	55 535	98.4	1.0	1.6
	0.18 – 0.5	Web	3	55 960	56 230	99.6	0.5	0.6
	....	Whole	..	.....	56 440	.....	...	...
24-in., 79.9-lb. I-Beam, Series 271	0.18 – 0.5	Toe	12	55 440	56 230	96.7	0.8	3.3
	0.18 – 0.5	Flange	6	56 240	56 795	97.7	0.7	2.3
	0.18 – 0.5	Root	6	61 500	63 145	108.6	1.9	8.6
	0.18 – 0.5	Web	3	58 200	58 950	101.4	0.9	1.4
	....	Whole	..	.....	58 150	.....	...	...
24-in., 100-lb. I-Beam, Series 271	0.18 – 0.5	Toe	12	57 920	59 150	99.0	0.9	1.2
	0.18 – 0.5	Flange	6	56 700	57 460	96.2	1.0	3.9
	0.18 – 0.5	Root	6	61 350	65 430	109.5	3.3	9.4
	0.18 – 0.5	Web	3	58 280	59 475	99.5	1.3	1.2
	....	Whole	..	.....	59 790	.....	...	...
24-in., 70-lb. Girder Beam, Series 281	0.05	Toe	8	54 160	56 590	99.5	2.5	2.6
	0.05	Intermediate	8	55 060	57 635	101.4	3.3	3.4
	0.05	Mid-Flange	8	50 760	55 985	98.5	3.6	3.6
	0.05	Root	8	54 790	58 235	102.4	4.5	4.6
	0.05	Web	4	54 240	56 775	99.8	4.4	4.4
	....	Whole	..	.....	56 910	.....	...	...

TABLE VI.—*Continued.*

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Tensile Strength				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
26-in., 160-lb. Girder Beam, Series 281...	0.05	Toe..........	8	55 050	55 615	99.0	0.8	1.1
	0.05	Intermediate..	8	54 360	55 185	98.2	1.2	1.9
	0.05	Mid-Flange...	8	53 450	55 435	98.7	1.8	1.8
	0.05	Root.........	8	56 140	56 800	101.1	0.7	1.1
	0.05	Web..........	4	57 640	58 170	103.5	0.8	3.5
	....	Whole........	..	.....	56 190	.....	...	...
14-in., 84-lb. H-Column, Series 281.	0.06	Toe..........	8	57 890	59 765	100.8	1.3	1.5
	0.06	Intermediate..	8	58 280	58 940	99.3	0.7	0.8
	0.06	Mid-Flange...	8	57 130	58 375	98.5	2.2	2.6
	0.06	Root.........	8	58 500	60 455	102.0	2.1	2.6
	0.06	Web..........	4	58 350	60 120	101.3	2.4	2.4
	....	Whole........	..	.....	59 340	.....	...	...
14-in., 288.5-lb. H-Column, Series 281.	0.06	Toe..........	8	58 090	58 865	102.3	0.8	2.2
	0.06	Intermediate..	8	50 730	56 735	98.6	3.0	2.5
	0.06	Mid-Flange...	8	53 450	56 365	98.0	1.7	2.2
	0.06	Root.........	8	55 650	57 195	99.3	1.4	1.5
	0.06	Web..........	4	57 760	58 085	100.9	0.4	0.9
	....	Whole........	..	.....	57 580	.....	...	...

sented by the given specimen. The mean values listed opposite "whole" in the tables were determined by calculating the weighted mean for each portion and averaging these weighted mean values.

Variability of Tensile Properties in Different Parts of Shapes:

In columns 5 and 6 of Tables V, VI, and VII are given the minimum and weighted mean values for drop-of-beam yield point, tensile strength, and percentage elongation for the specimens considered (not annealed) of these two series of tests. Column 7 of each table lists the percentage of the mean value for the specimens from a given location to the weighted mean value for the whole shape. Therefore the percentages in column 7 indicate how closely the specimens from a given location represent the whole shape. Indices of the uniformity of the results obtained by testing specimens from a given location are found in columns 8 and 9. The average variation from the mean in column 8 is based on the mean value in column 6 for the location designated in column 3. Column 9 shows average percentage variation from grand mean for the shape.

Considering first the specimens from plates, it will be noted from Tables V, VI, and VII, and Fig. 2, that the intermediate specimens exhibit mean yield points and tensile strengths slightly less than the mean values for specimens from the edge or center, whereas the elongation values are approximately the same as the mean values for the

TABLE VII.—MINIMUM AND MEAN PERCENTAGE ELONGATIONS IN 8 IN. OF TENSION SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NOS. 271 AND 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Elongation in 8 in.				
				Minimum, per cent	Mean, per cent	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	2	3	4	5	6	7	8	9
$\frac{3}{8}$-in. Plate, Series 281	0.5	Edge	4	27.0	30.6	101.7	11.4	11.7
	0.5	Intermediate	4	27.5	30.6	101.7	8.5	8.6
	0.5	Center	4	27.0	29.4	97.7	7.2	7.2
	0.5	Whole	..	....	30.1	.....	....	....
$\frac{7}{8}$-in. Plate, Series 281	0.5	Edge	4	31.0	32.5	100.9	4.6	4.3
	0.5	Intermediate	4	31.0	32.4	100.6	2.2	2.5
	0.5	Center	4	30.5	31.8	98.8	2.2	2.5
	...	Whole	..	....	32.2	.....	...	...
12 by $\frac{3}{8}$-in. Plate, Series 271	0.18 – 0.5	Edge	6	22.8	27.1	96.6	8.0	8.8
	0.18 – 0.5	Center	3	28.2	29.0	103.4	3.4	3.5
	...	Whole	..	....	28.0	.....	...	...
12 by $\frac{7}{8}$-in. Plate, Series 271	0.18 – 0.5	Edge	6	23.9	30.3	97.8	9.5	9.3
	0.18 – 0.5	Center	3	30.8	31.7	102.2	3.2	2.6
	....	....	..	....	31.0	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle, Series 281	0.5	Toe	8	26.2	28.1	107.9	2.5	7.9
	0.5	Root	4	21.0	24.0	92.1	6.3	7.7
	...	Whole	..	....	26.0	.....	...	...
8 by 8 by 1-in. Angle, Series 281	0.5	Toe	8	25.8	29.6	111.5	9.3	12.7
	0.5	Root	4	21.2	23.5	88.5	6.0	11.3
	...	Whole	..	....	26.5	.....	...	...
6 by 6 by $\frac{3}{8}$-in. Angle, Series 271	0.18 – 0.5	Toe	6	24.8	26.0	106.1	2.3	4.8
	0.18 – 0.5	Root	3	20.8	23.0	92.9	9.6	8.9
	....	Whole	..	....	24.8	.....	...	...
6 by 6 by $\frac{7}{8}$-in. Angle, Series 271	0.18 – 0.5	Toe	6	29.2	31.3	99.8	4.4	4.4
	0.18 – 0.5	Root	3	28.8	31.4	100.2	6.5	6.4
	....	Whole	..	....	31.3	.....	...	...
15-in., 35-lb. Channel, Series 271	0.18 – 0.5	Toe	6	19.5	22.9	79.8	9.7	20.3
	0.18 – 0.5	Root	6	23.0	27.4	95.5	7.5	8.2
	0.18 – 0.5	Web	3	31.2	33.1	115.3	6.3	15.2
	....	Whole	..	....	28.7	.....	...	...
15-in., 55-lb. Channel, Series 271	0.18 – 0.5	Toe	6	17.0	20.9	68.3	13.8	31.7
	0.18 – 0.5	Root	6	28.4	31.2	116.5	6.9	3.9
	0.18 – 0.5	Web	3	29.8	32.6	166.0	5.6	8.2
	....	Whole	..	....	30.6	.....	...	...
24-in., 79.9-lb. I-Beam, Series 271	0.18 – 0.5	Toe	12	23.4	27.4	97.8	5.1	4.9
	0.18 – 0.5	Flange	6	28.0	29.9	106.8	3.7	6.7
	0.18 – 0.5	Root	5	11.2	17.4	62.2	16.3	37.7
	0.18 – 0.5	Web	3	27.0	30.6	109.3	7.7	11.5
	....	Whole	..	....	28.0	.....	...	...
24-in., 100-lb. I-Beam, Series 271	0.18 – 0.5	Toe	11	23.0	26.7	93.4	5.5	8.1
	0.18 – 0.5	Flange	6	32.2	33.3	116.5	3.2	16.6
	0.18 – 0.5	Root	4	16.4	23.6	82.5	25.7	21.5
	0.18 – 0.5	Web	3	27.5	28.6	100.0	2.7	2.7
	....	Whole	..	....	28.6	.....	...	...
24-in., 70-lb. Girder Beam, Series 281	0.05	Toe	8	23.0	26.8	92.8	7.1	8.1
	0.05	Intermediate	8	28.3	29.7	102.8	3.1	3.8
	0.05	Mid-Flange	8	26.2	30.2	104.5	4.6	6.6
	0.05	Root	8	23.9	25.8	89.3	5.6	10.7
	0.05	Web	4	26.1	29.4	101.7	7.1	7.2
	....	Whole	..	....	28.9	.....	...	...

TABLE VII.—*Continued.*

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Elongation in 8 in.				
				Minimum, per cent	Mean, per cent	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
26-in., 160-lb. Girder Beam, Series 281...	0.05	Toe..........	8	25.8	31.8	98.2	9.1	8.9
	0.05	Intermediate..	8	30.1	33.6	103.7	4.7	6.1
	0.05	Mid-Flange...	8	22.5	32.5	100.3	10.5	10.4
	0.05	Root.........	8	28.9	32.6	100.6	7.0	7.0
	0.05	Web.........	4	29.8	31.5	97.2	3.8	4.3
	....	Whole........	..	....	32.4	.....	...	...
14-in., 84-lb. H-Column, Series 281.	0.06	Toe..........	8	26.2	30.0	99.4	4.3	4.3
	0.06	Intermediate..	8	27.1	30.4	100.6	4.6	4.8
	0.06	Mid-Flange...	8	28.0	31.4	104.0	7.5	7.7
	0.06	Root.........	8	23.5	27.9	92.4	9.0	9.6
	0.06	Web.........	4	24.6	28.4	94.1	6.7	5.9
	....	Whole........	..	....	30.2	.....	...	...
14-in., 288.5-lb. H-Column, Series 281.	0.06	Toe..........	8	23.6	31.7	109.7	7.6	14.0
	0.06	Intermediate..	8	15.8	30.0	103.8	11.8	15.1
	0.06	Mid-Flange...	8	22.5	25.8	89.3	8.1	11.5
	0.06	Root.........	7	19.0	26.9	93.1	8.3	9.5
	0.06	Web.........	4	25.0	27.7	95.9	6.0	7.1
	....	Whole........	..	....	28.9	.....	...	...

whole plates. The average variations in per cent for the different specimens is small, excepting the $\frac{7}{8}$-in. plates of Series No. 271. In the Wisconsin Tests for the American Society of Civil Engineers,[1] tests of specimens from the centers of 11 pieces of 12 by $\frac{1}{4}$-in. plate gave somewhat more uniform and slightly lower values of yield point and tensile strength than specimens obtained from the edges of the same plates. Although the data are not conclusive, it appears that the intermediate specimens are the most satisfactory, with center specimens next in order of value.

For the equal legged angles of these tests the toe specimens gave more uniform and considerably lower values of the yield point and in most cases lower and less variable values of strength and ductility than the root specimens.

Chemical analyses of the fractured root specimens from the 8 by 8 by 1-in. angles from heat No. 22591 show that they contained 0.34 per cent of carbon and 0.44 per cent of manganese, whereas the toe specimens from the same angles carried only 0.17 per cent of carbon and 0.40 per cent of manganese. This segregation of carbon in the root specimens was undoubtedly the major reason for the yield point of the root specimens being 4300 lb. per sq. in. higher than the yield point of the toe specimens.

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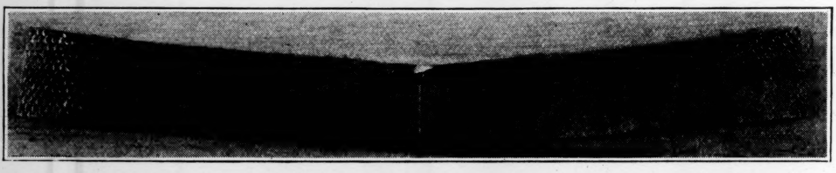
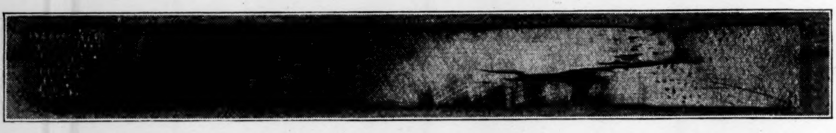
[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 105 (1928).

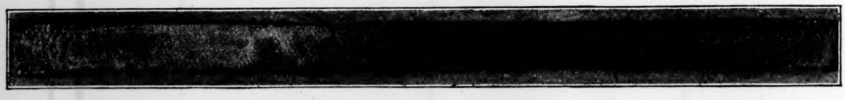
The web specimens from the 15-in. channels had the lowest yield points of the specimens tested, represented best the tensile strengths of the whole shapes, but gave the highest ductility values. They also gave uniform results. The toe specimens exhibited the lowest ductility. The Wisconsin tests, previously cited, on web, toe, and root specimens from 16 pieces of 10-in., 20-lb. channel, indicated that the web specimens were most uniform, best represented the yield point and tensile strength, but gave the highest elongation.



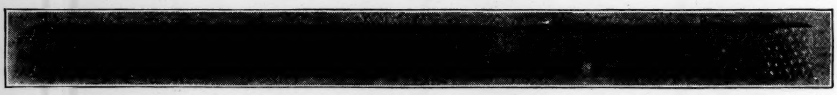
(*a*) H-87; yield point, 25,960 lb. per sq. in.; tensile strength, 53,450 lb. per sq. in.



(*b*) H-82; yield point, 30,400 lb. per sq. in.; tensile strength, 50,730 lb. per sq. in. Note slag inclusion.



(*c*) H-75; yield point, 31,980 lb. per sq. in.; tensile strength, 58,410 lb. per sq. in.



(*d*) H-66; yield point, 31,020 lb. per sq. in.; tensile strength, 55,650 lb. per sq. in.

FIG. 3.—Fractures of Specimens from 288.5-lb. H-Columns.
(For locations see Figs. 1 or 4.)

The data on the 24-in., 79.9-lb. I-beams show that the web specimens best represented the yield point and tensile strength of the whole shape. For the 24-in., 100-lb. I-beam the toe specimens were somewhat better representatives of the strength values than the web specimens. In both of these sections the lowest values of yield point and tensile strength were obtained from the mid-flange specimens. The elongation measurements on the toe and web specimens well represent the ductility of the whole I-beams. Root specimens gave the highest and most variable yield points and the least and most variable elongations.

For the girder beams and H-columns, the intermediate specimens, numbered 2 in Fig. 1, gave yield points and tensile strengths which in most cases best represented the whole shapes. These specimens also gave satisfactory indices of elongation of the whole shapes. Similar findings are reported by Tuckerman and Stang[1] in tests of eighteen 14-in. H-columns and by Withey in the previously mentioned Wisconsin tests on eight 32-lb. H-columns.

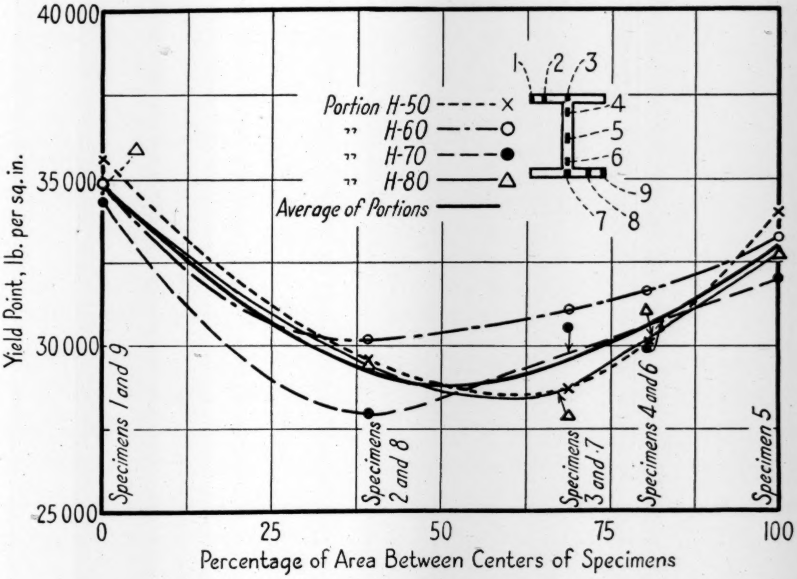


FIG. 4.—Range in Yield Point by Drop of Beam for Specimens Cut from Different Parts of 14-in., 288.5-lb. H-Columns.

Specimens from three of the four portions of heavy H-columns exhibited flaws at failure as shown in Fig. 3. Chemical analyses of the metal at fractures showed no evidence of segregation of carbon or manganese. The location from which these specimens were taken can be ascertained from the legend in Fig. 4. The range in yield point for specimens from these 288.5-lb. H-columns is well shown in Fig. 4. The flaws in the material of H-80 undoubtedly contributed to the irregular disposition of points representing it on the diagram. Whereas the pipe flaws in H-80 materially reduced the yield points and to some extend the tensile strengths of the specimens containing them, as can be seen from the data in Table V, they did not seriously affect either the weighted mean yield point or tensile strength for the shape. For this particular group of H-columns the root specimen best represented the whole in yield point and tensile strength. So far as available data on such heavy shapes indicate, a single specimen from a given location does not give a reliable measure of the strength properties of the whole shape. Weighted mean values derived from a number of locations as in this series of tests are more satisfactory, but their determination is laborious and expensive. Tentatively, the average of results from three specimens, the intermediate flange, root, and web, is suggested as a substitute.

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[1] U. S. Bureau of Standards *Technologic Paper No. 328*, p. 79.

TABLE VIII.—YIELD POINTS IN TENSION OF ANNEALED SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NO. 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Yield Point				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	2	3	4	5	6	7	8	9
$\frac{3}{8}$-in. Plate	0.5	Edge	2	28 300	29 200	98.7	3.1	3.0
	0.5	Intermediate	2	28 450	29 630	100.2	4.0	4.0
	0.5	Center	2	28 530	29 680	100.4	3.9	3.9
	...	Whole	..	.....	29 580	.....	...	...
$\frac{7}{8}$-in. Plate	0.5	Edge	2	28 820	29 835	100.6	3.4	3.4
	0.5	Intermediate	2	28 350	29 320	98.9	3.3	3.3
	0.5	Center	2	28 580	29 980	101.1	4.7	4.7
	...	Whole	..	.....	29 650	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle	0.5	Toe	4	26 930	28 025	97.8	3.6	3.5
	0.5	Root	2	29 120	29 270	102.1	0.5	2.2
	...	Whole	..	.....	28 640	.....	...	...
8 by 8 by 1-in. Angle	0.5	Toe	4	25 760	30 550	98.5	15.6	15.4
	0.5	Root	2	30 090	31 495	101.5	4.5	4.5
	...	Whole	..	.....	31 020	.....	...	...
24-in., 70-lb. Girder Beam	0.05	Toe	4	28 050	29 040	96.2	2.7	3.8
	0.05	Intermediate	4	28 880	30 395	100.7	3.2	3.2
	0.05	Mid-Flange	4	28 620	30 090	99.6	2.9	3.0
	0.05	Root	4	28 510	30 040	99.6	5.0	5.0
	0.05	Web	2	29 860	30 440	100.9	1.9	1.9
	....	Whole	..	.....	30 180	.....	...	...
26-in., 160-lb. Girder Beam	0.05	Toe	4	27 720	28 290	98.0	1.5	2.3
	0.05	Intermediate	4	28 270	28 665	99.2	1.7	2.1
	0.05	Mid-Flange	4	27 590	28 720	99.4	2.3	2.3
	0.05	Root	4	28 535	29 150	100.9	1.3	1.5
	0.05	Web	1[a]	29 640	29 640	102.6	...	2.5
	....	Whole	..	.....	28 910	.....	...	...

[a] Companion web specimen, yield point 64,470 lb. per sq. in., omitted from computations.

Effect of Annealing on the Variation of Yield Point with Location of Specimen in Shapes:

In order to ascertain whether the variation in yield point and other properties of specimens cut from different parts of shapes was due to differences in composition or to other causes, such as differences in temperature of rolling and mechanical work, the specimens from plates, angles, and girder beams of Series No. 281 were annealed. The specimens from the 26-in. 160-lb. girder beam were slowly heated in an electric furnace to 1650° F., held at that temperature one hour and cooled slowly in the furnace. The other specimens were treated in similar manner excepting the temperature was 1620° F.

TABLE IX.—TENSILE STRENGTHS OF ANNEALED SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NO. 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Tensile Strength				
				Minimum, lb. per sq. in.	Mean, lb. per sq. in.	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	2	3	4	5	6	7	8	9
$\frac{3}{8}$-in. Plate..........	0.5	Edge.........	2	44 430	44 855	97.0	0.9	3.1
	0.5	Intermediate..	2	45 460	45 720	98.8	0.6	1.2
	0.5	Center........	2	46 230	47 565	102.8	2.8	2.9
	...	Whole........	..	.....	46 290	.....	...	...
$\frac{7}{8}$-in. Plate...........	0.5	Edge.........	2	47 370	48 135	97.6	1.6	2.4
	0.5	Intermediate..	2	47 620	48 525	98.4	1.9	1.8
	0.5	Center........	2	49 870	50 735	102.9	1.7	2.9
	...	Whole........	..	.....	49 310	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle	0.5	Toe..........	4	45 800	47 695	99.5	3.6	3.7
	0.5	Root.........	2	47 480	48 165	100.5	1.4	1.4
	...	Whole........	..	.....	47 920	.....	...	...
8 by 8 by 1-in. Angle.	0.5	Toe..........	4	45 950	49 060	93.1	6.3	6.9
	0.5	Root.........	2	54 520	56 310	106.9	3.2	6.9
	...	Whole........	..	.....	52 680	.....	...	...
24-in., 70-lb. Girder Beam............	0.05	Toe..........	4	49 060	50 505	100.3	2.7	2.7
	0.05	Intermediate..	4	48 900	50 330	100.0	2.8	2.8
	0.05	Mid-Flange...	4	48 270	50 400	100.1	3.3	3.3
	0.05	Root.........	4	47 850	50 070	99.5	4.1	4.1
	0.05	Web.........	2	48 580	50 365	100.0	3.5	3.5
	....	Whole........	..	.....	50 350	.....	...	...
26-in., 160-lb. Girder Beam............	0.05	Toe..........	4	49 410	49 900	96.3	0.7	3.7
	0.05	Intermediate..	4	49 360	50 545	97.5	1.2	2.5
	0.05	Mid-Flange...	4	50 260	51 725	99.8	2.1	2.1
	0.05	Root.........	4	52 330	52 770	101.8	0.8	1.8
	0.05	Web.........	1[a]	54 260	54 260	104.7	...	4.7
	....	Whole........	..	.....	51 820	.....	...	...

[a] Companion web specimen, tensile strength 90,180 lb. per sq. in., omitted from computations.

Tables VIII, IX, and X contain the data for the annealed specimens, comparing yield points of the normal and gagged specimens in Table V with those of the corresponding annealed specimens in Table VIII it will be observed that in most cases the yield points of the annealed specimens were markedly lower, as would be expected, and also that the percentages of the whole for them are nearer one hundred than the percentages of the whole for the normal and gagged specimen. One of the web specimens from a 26-in., 160-lb. girder beam gave an exceptionally high yield point and tensile strength.

Chemical analyses at fracture indicated carbon 0.18 per cent, manganese 0.58 per cent, phosphorus 0.021 per cent, sulfur 0.050 per cent, silicon 0.03 per cent. Photomicrographs show that marked banding of the ferrite occurred in this specimen.

TABLE X.—PERCENTAGE ELONGATION IN 8 IN. OF ANNEALED TENSION SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NO. 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Elongation in 8-in.				
				Minimum, per cent	Mean, per cent	Percentage of Whole	Average Variation, per cent	
							From Mean	From Grand Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
$\frac{3}{8}$-in. Plate..........	0.5	Edge.........	2	32.2	33.2	103.6	3.0	3.7
	0.5	Intermediate..	2	28.8	31.5	98.3	8.6	8.4
	0.5	Center........	2	31.2	32.1	100.2	2.8	2.8
	...	Whole........	..	....	32.0	.....	...	...
$\frac{7}{8}$-in. Plate..........	0.5	Edge.........	2	33.8	33.8	100.0	0.0	0.0
	0.5	Intermediate..	2	32.8	33.3	98.5	1.5	1.5
	0.5	Center........	2	33.3	34.4	101.8	3.2	3.3
	...	Whole........	..	....	33.8	.....	...	...
8 by 8 by $\frac{1}{2}$-in. Angle	0.5	Toe..........	4	29.8	33.5	101.5	7.1	7.2
	0.5	Root.........	2	32.5	32.5	98.5	0.0	1.5
	...	Whole........	..	....	33.0	.....	...	...
8 by 8 by 1-in. Angle.	0.5	Toe..........	4	28.2	32.2	104.9	6.8	8.8
	0.5	Root.........	2	28.5	29.2	95.1	2.4	4.8
	...	Whole........	..	....	30.7	.....	...	...
24-in., 70-lb. Girder Beam............	0.05	Toe..........	..	31.1	33.0	98.8	2.9	2.3
	0.05	Intermediate..	4	32.8	34.3	102.7	4.2	4.4
	0.05	Mid-Flange...	4	32.2	32.8	98.3	1.1	1.5
	0.05	Root.........	4	30.0	33.0	98.8	5.5	6.0
	0.05	Web.........	2	30.1	33.3	99.7	9.7	9.6
	....	Whole........	..	....	33.4	.....	...	...
26-in., 160-lb. Girder Beam............	0.05	Toe..........	4	29.6	32.8	97.2	8.5	8.1
	0.05	Intermediate..	4	33.3	35.5	105.2	4.2	5.7
	0.05	Mid-Flange...	4	31.8	34.4	101.8	6.2	6.3
	0.05	Root.........	4	30.0	31.8	94.2	4.3	6.2
	0.05	Web.........	1[a]	32.3	32.3	95.7	...	...
	....	Whole........	..	....	33.8	.....	...	...

[a] Companion web specimen, percentage elongation 15.0, omitted from computations.

Comparing results in Tables VI and IX, it will be noted that the mean tensile strengths of the annealed specimens from different locations varied but little from the weighted mean strength for the whole shape. Two exceptions appear, one already described, the other in the tests of the specimens from the 8 by 8 by 1-in. angles in which the annealed root specimens were much stronger than the annealed toe specimens. This discrepancy is probably due to the segregation of carbon and manganese, as previously mentioned, in the root specimens from one of the heats.

Comparing elongations in Tables VII and X, it appears that in most cases annealing reduced the discrepancies in ductility of specimens from different locations.

The above comparisons between the annealed and unannealed specimens show that in nearly all cases the discrepancies in yield point and other properties of the unannealed specimens, associated with differences in location of specimen in shape were due to causes other than differences in composition.

TABLE XI.—RATIOS OF YIELD POINT IN TENSION TO TENSILE STRENGTH OF ANNEALED SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NO. 281.

Shape	Speed of Head at Yield Point, in. per minute	Location of Specimen	Number of Specimens Tested	Ratio of Yield Point to Tensile Strength					
				Based on Individual Specimens		Based on Weighted Grand Mean Tensile Strength for Shape		Based on Mean Tensile Strength of Representative Specimens for Shape	
				Minimum	Average	Minimum	Average	Minimum	Average
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
$\frac{3}{8}$-in. Plate......	0.5	Edge........	2	0.637	0.651	0.611	0.631	.....	.....
	0.5	Intermediate[a]	2	0.626	0.648	0.615	0.640	0.622	0.648
	0.5	Center.......	2	0.618	0.624	0.616	0.641	.....	.....
	...	Whole.......	..	0.621	0.639	0.615	0.639	.....	.....
$\frac{7}{8}$-in. Plate......	0.5	Edge........	2	0.609	0.620	0.584	0.605	.....	.....
	0.5	Intermediate[a]	2	0.594	0.604	0.575	0.595	0.584	0.604
	0.5	Center.......	2	0.573	0.591	0.579	0.608	.....	.....
	...	Whole.......	..	0.576	0.601	0.578	0.601	.....	.....
8-in. by 8-in. by $\frac{1}{2}$-in. Angle...	0.5	Toe[a]........	4	0.586	0.588	0.562	0.584	0.565	0.588
	0.5	Root........	2	0.613	0.608	0.607	0.611	.....	.....
	...	Whole.......	..	0.571	0.598	0.589	0.598	.....	.....
8-in. by 8-in. by 1-in. Angle....	0.5	Toe[a]........	4	0.560	0.623	0.488	0.579	0.525	0.623
	0.5	Root........	2	0.551	0.559	0.571	0.597	.....	.....
	...	Whole.......	..	0.537	0.589	0.530	0.589	.....	.....
24-in., 70-lb. Girder Beam..	0.05	Toe.........	4	0.572	0.575	0.557	0.577	.....	.....
	0.05	Intermediate.	4	0.590	0.604	0.573	0.604	.....	.....
	0.05	Mid-Flange..	4	0.593	0.597	0.568	0.597	.....	.....
	0.05	Root........	4	0.596	0.600	0.566	0.596	.....	.....
	0.05	Web[a].......	2	0.615	0.604	0.593	0.604	0.593	0.604
	....	Whole.......	..	0.596	0.600	0.584	0.600	.....	.....
26 in., 160-lb. Girder Beam..	0.05	Toe.........	4	0.561	0.567	0.535	0.546	.....	.....
	0.05	Intermediate.	4	0.573	0.567	0.545	0.553	.....	.....
	0.05	Mid-Flange..	4	0.549	0.556	0.532	0.554	.....	.....
	0.05	Root........	4	0.545	0.553	0.550	0.562	.....	.....
	0.05	Web[a].......	2	0.546	0.652	0.572	0.572	0.546	0.546
	....	Whole.......	..	0.552	0.558	0.556	0.558	.....	.....

[a] Ratios in columns 9 and 10 based on these specimens.

Relationship of Yield Point to Ultimate Strength:

In Table XI are compiled ratios of yield point to tensile strength for the annealed specimens of Series No. 281. Based on grand mean strengths, the ratios for the whole shapes range between 0.56 and

TABLE XII.—RATIOS OF YIELD POINT IN TENSION TO TENSILE STRENGTH OF SPECIMENS CUT FROM DIFFERENT PARTS OF STRUCTURAL STEEL SHAPES—SERIES NOS. 271 AND 281.

Shape	Location of Specimen	Number of Specimens Tested	Ratio of Yield Point to Tensile Strength					
			Based on Individual Specimens		Based on Weighted Grand Mean Tensile Strength for Shape		Based on Mean Tensile Strength of Representative Specimens for Shape	
			Minimum	Average	Minimum	Average	Minimum	Average
1	2	3	4	5	6	7	8	9
$\frac{3}{8}$-in. Plate, Series 281	Edge	4	0.627	0.634	0.606	0.623	.....	.....
	Intermediate[a]	4	0.612	0.622	0.591	0.611	0.601	0.621
	Center	4	0.602	0.612	0.604	0.629	.....	.....
	Whole	..	0.609	0.620	0.598	0.620	.....	.....
$\frac{7}{8}$-in. Plate, Series 281	Edge	4	0.571	0.580	0.555	0.573	.....	.....
	Intermediate[a]	4	0.549	0.559	0.534	0.554	0.538	0.558
	Center	4	0.547	0.554	0.557	0.563	.....	.....
	Whole	..	0.555	0.560	0.550	0.560	.....	.....
12 by $\frac{3}{8}$-in. Plate, Series 271	Edge[a]	6	0.596	0.619	0.598	0.621	0.595	0.619
	Center	3	0.593	0.605	0.591	0.603	.....	.....
	Whole	..	0.600	0.612	0.601	0.612	.....	.....
12 by $\frac{7}{8}$-in. Plate, Series 271	Edge[a]	6	0.52	0.528	0.528	0.541	0.516	0.528
	Center	3	0.467	0.485	0.453	0.473	.....	.....
	Whole	..	0.492	0.507	0.491	0.507	.....	.....
8 by 8 by $\frac{1}{2}$-in. Angle, Series 281	Toe[a]	8	0.552	0.600	0.516	0.575	0.538	0.599
	Root	4	0.635	0.676	0.540	0.703	.....	.....
	Whole	..	0.603	0.639	0.606	0.639	.....	.....
8 by 8 by 1-in. Angle, Series 281	Toe[a]	8	0.578	0.620	0.512	0.587	0.541	0.620
	Root	4	0.530	0.594	0.535	0.625	.....	.....
	Whole	..	0.538	0.606	0.537	0.606	.....	.....
6 by 6 by $\frac{3}{8}$-in. Angle, Series 271	Toe[a]	6	0.628	0.637	0.610	0.622	0.625	0.638
	Root	3	0.668	0.673	0.674	0.690	.....	.....
	Whole	..	0.647	0.656	0.644	0.656	.....	.....
6 by 6 by $\frac{7}{8}$-in. Angle, Series 271	Toe[a]	6	0.539	0.571	0.539	0.577	0.533	0.571
	Root	2	0.536	0.555	0.526	0.548	.....	.....
	Whole	..	0.554	0.564	0.551	0.564	.....	.....
15-in., 35-lb. Channel, Series 271	Toe	6	0.685	0.700	0.697	0.723	.....	.....
	Root	6	0.648	0.668	0.628	0.655	.....	.....
	Web[a]	3	0.628	0.637	0.621	0.638	0.619	0.637
	Whole	..	0.645	0.662	0.643	0.662	.....	.....
15-in., 55-lb. Channel, Series 271	Toe	6	0.666	0.680	0.687	0.717	.....	.....
	Root	6	0.547	0.559	0.534	0.550	.....	.....
	Web[a]	3	0.518	0.538	0.515	0.536	0.517	0.538
	Whole	..	0.553	0.564	0.550	0.564	.....	.....
24-in., 79.9-lb. I-Beam Series 271	Toe	12	0.518	0.590	0.494	0.570	.....	.....
	Flange	6	0.480	0.531	0.469	0.518	.....	.....
	Root	6	0.692	0.723	0.737	0.784	.....	.....
	Web[a]	3	0.535	0.579	0.543	0.587	0.535	0.579
	Whole	..	0.559	0.588	0.559	0.588	.....	.....
24-in., 100-lb. I-Beam, Series 271	Toe	12	0.529	0.591	0.513	0.585	.....	.....
	Flange	6	0.489	0.498	0.468	0.479	.....	.....
	Root	5	0.685	0.745	0.703	0.830	.....	.....
	Web[a]	3	0.508	0.517	0.503	0.514	0.506	0.517
	Whole	..	0.557	0.568	0.550	0.568	.....	.....
24-in., 70-lb. Girder Beam, Series 281	Toe	8	0.556	0.567	0.532	0.564	.....	.....
	Intermediate	8	0.520	0.526	0.512	0.533	.....	.....
	Mid-Flange	8	0.542	0.525	0.483	0.516	.....	.....
	Root	8	0.572	0.617	0.550	0.632	.....	.....
	Web[a]	4	0.579	0.568	0.552	0.567	0.553	0.568
	Whole	..	0.545	0.554	0.539	0.554	.....	.....

[a] Ratios in columns 8 and 9 based on these specimens.

TABLE XII.—*Continued.*

Shape	Location of Specimen	Number of Specimens Tested	Ratio of Yield Point to Tensile Strength					
			Based on Individual Specimens		Based on Weighted Grand Mean Tensile Strength for Shape		Based on Mean Tensile Strength of Representative Specimens for Shape	
			Minimum	Average	Minimum	Average	Minimum	Average
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
26-in., 160-lb. Girder Beam, Series 281......	Toe..........	8	0.585	0.609	0.576	0.603	.....	.....
	Intermediate..	8	0.527	0.542	0.511	0.532	.....	.....
	Mid-Flange...	8	0.485	0.499	0.469	0.492	.....	.....
	Root..........	8	0.563	0.569	0.563	0.576	.....	.....
	Web[a].........	4	0.609	0.617	0.630	0.638	0.608	0.616
	Whole........	..	0.555	0.566	0.558	0.566	.....	.....
14-in., 84-lb., H-Column, Series 281............	Toe..........	8	0.630	0.634	0.615	0.638	.....	.....
	Intermediate..	8	0.554	0.582	0.549	0.578	.....	.....
	Mid-Flange...	8	0.526	0.564	0.534	0.555	.....	.....
	Root..........	8	0.576	0.598	0.597	0.609	.....	.....
	Web[a].........	4	0.599	0.627	0.618	0.635	0.610	0.626
	Whole........	..	0.580	0.592	0.583	0.592	.....	.....
14-in., 288.5-lb. H-Column, Series 281	Toe..........	8	0.577	0.593	0.582	0.606	.....	.....
	Intermediate..	8	0.548	0.516	0.483	0.508	.....	.....
	Mid-Flange...	8	0.486	0.525	0.451	0.513	.....	.....
	Root..........	8	0.504	0.536	0.491	0.532	.....	.....
	Web[a].........	4	0.547	0.567	0.555	0.572	0.550	0.567
	Whole........	..	0.531	0.541	0.530	0.541	.....	.....

[a] Ratios in columns 8 and 9 based on these specimens.

0.64; based on representative specimens, the ratios range between 0.55 and 0.65.

Considering the ratios of yield point to tensile strength for normal, gagged, and skid specimens, Table XII, a wider range in the ratio is noted. Based on the grand mean tensile strength for the shape, the minimum ratios for whole shapes range from 0.49 to 0.64, whereas the mean ratios for whole shapes range from 0.51 to 0.66. If ratios are based on data from representative specimens, the minimum ratios range from 0.51 to 0.62 and the mean ratios range from 0.53 to 0.64. The range in the ratio of yield point to tensile strength based on individual whole shapes is shown in Fig. 5. It will be noted that the ratio is lower for the thick shapes than for the thin shapes.

Considering individual whole shapes, 48 per cent of the total number tested had ratios of yield point to tensile strength within 5 per cent of the mean ratio (0.59) and 82 per cent had ratios within 10 per cent of that mean value.

The Range in Tensile Properties of the Shapes Tested:

Table XIII shows ranges in yield point, tensile strength and percentage elongation for a single representative specimen from each portion of shape tested. The representative specimens used are indicated in Table XII. The locations for these representative specimens are those common in present practice. Of the 56 portions of shapes tested, all of which had come from heats passing, by mill tests, the specification requirements, it will be observed that in the cooperating laboratory tests four, or 7 per cent, failed by a small margin to pass the yield point requirements and thirteen, or 23 per cent, failed to pass the tensile strength requirement, but all passed the ductility requirements.

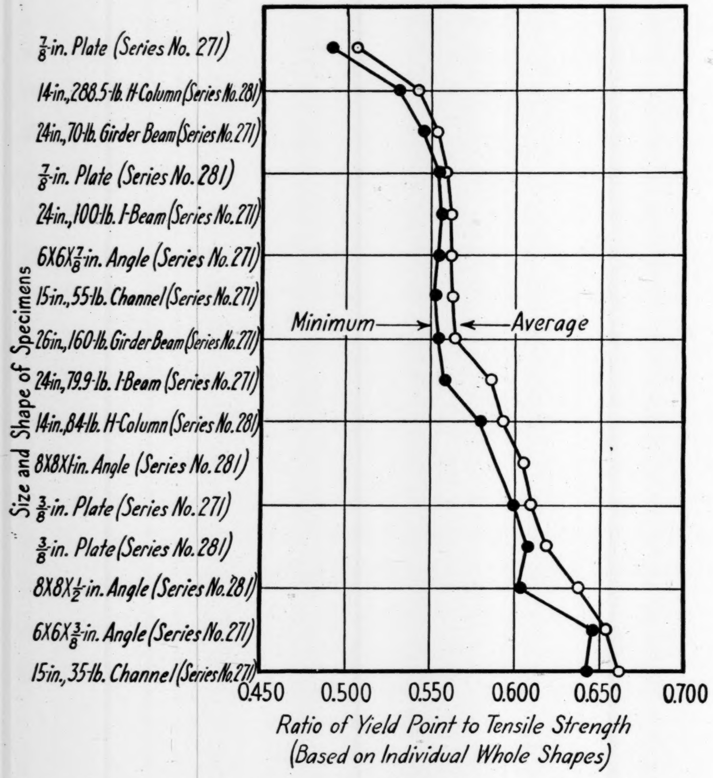

FIG. 5.—Range in the Ratio of Yield Point to Tensile Strength.

Although the number of specimens tested is small, some idea of the uniformity of the individual shapes of a given type is afforded by the data in columns 6, 9, and 12 of Table XIII. The average percentage variation from the mean yield point for a given shape was less than 3 per cent in 11 shapes out of 16 tested but reached 5.4 per cent in one case. The average percentage variation from the mean tensile strength for a given shape was less than 3 per cent in 14 shapes and reached 6.0 per cent in one case.

The variation from the mean ductility for a given shape was in most cases considerably greater than the variation in strength properties. For 6 shapes the average percentage variation from the mean percentage elongation was above 7 per cent.

TABLE XIII.—RANGES IN TENSILE PROPERTIES OF DIFFERENT SHAPES TESTED BASED ON ONE REPRESENTATIVE SPECIMEN FOR EACH PORTION OF SHAPE TESTED.

Shape	Number of Portions of Shape Tested	Heat Number	Yield Point			Tensile Strength			Elongation in 8 in.		
			Minimum, lb. per sq. in.	Maximum, lb. per sq. in.	Average Variation, per cent from Mean	Minimum, lb. per sq. in.	Maximum, lb. per sq. in.	Average Variation, per cent from Mean	Minimum, per cent	Maximum, per cent	Average Variation, per cent from Mean
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
$\frac{3}{8}$-in. Plate Series 281	4	25 602 16 636	32 150	33 780	2.4	52 520	54 400	1.7	27.5	33.8	8.5
$\frac{7}{8}$-in. Plate, Series 281	4	19 603 21 664	29 450	31 560	3.1	53 500	55 900	2.1	31.0	33.0	2.2
$\frac{3}{8}$-in. Plate, Series 271	3	929 023	35 080	37 800	2.4	58 080	59 670	0.7	22.8	31.2	8.0
$\frac{7}{8}$-in. Plate, Series 271	3	919 733	31 740	33 270	1.5	60 810	62 400	0.8	23.9	35.2	9.5
8 by 8 by $\frac{1}{2}$-in. Angle, Series 281.........	4	24 571 920 365	30 600	35 860	4.0	55 200	61 260	2.5	26.2	29.2	2.5
8 by 8 by 1-in. Angle, Series 281.........	4	22 591 18 416	30 760	38 870	5.4	53 220	61 120	6.0	25.8	32.8	9.3
6 by 6 by $\frac{3}{8}$-in. Angle, Series 271.........	3	16 626	37 065	38 880	1.1	58 660	60 250	0.7	24.8	26.8	2.3
6 by 6 by $\frac{7}{8}$-in. Angle, Series 271.........	3	21 698	29 750	34 390	3.3	55 220	56 640	0.9	29.2	33.0	4.4
15-in., 35-lb. Channel, Series 271.........	3	13 581	33 510	35 650	2.3	53 330	54 950	1.0	31.2	36.2	6.3
15-in., 55-lb. Channel, Series 271.........	3	919 611	29 090	31 470	2.7	55 960	56 630	0.5	29.8	34.0	5.6
24-in., 79.9-lb. I-Beam, Series 271.........	3	15 596	31 540	36 200	5.1	58 200	59 750	0.9	27.0	33.5	7.4
24-in., 100-lb. I-Beam, Series 271.........	3	18 548	30 080	31 730	2.1	58 280	60 170	1.3	27.5	29.5	2.7
24-in., 70-lb. Girder Beam, Series 281...	4	21 676 24 631	31 400	33 050	2.0	54 240	59 530	4.4	26.1	31.6	7.1
26-in., 160-lb. Girder Beam, Series 281...	4	41J 002 42J 002	35 390	36 855	1.4	57 640	59 110	0.8	29.8	32.8	3.8
14-in., 84-lb. H-Column, Series 281.	4	31H 606 43H 539	36 680	38 730	2.2	58 350	61 820	2.4	24.6	30.2	6.7
14-in., 288.5-lb. H-Column, Series 281.	4	32H 532 41H 454	31 980	33 930	1.9	57 760	58 410	0.4	25.0	30.6	6.0

Considering the data in Table XIII it will be noted that the yield point ranged from a minimum value of 29,090 lb. per sq. in. for

TABLE XIV.—RANGES IN AVERAGE STRENGTH AND ELONGATION PROPERTIES OF TEST SPECIMENS.

Property Tested	Average of Means	Highest Average Value and Elongation	Shape Having Highest Value	Lowest Average Value	Shape Having Lowest Value	Ratio, Highest-Lowest Specified Minimum, per cent
1	*2*	*3*	*4*	*5*	*6*	*7*
Yield Point, lb. per sq. in.	33 803	39 870	6 by 6 by $\frac{3}{8}$-in. Angle[a]	30 485	12 by $\frac{7}{8}$-in. Plate[a]	31.3
Tensile Strength, lb. per sq. in.	57 592	60 785	6 by 6 by $\frac{3}{8}$-in. Angle[b]	54 010	15-in., 35-lb. Channel[a]	12.3
Elongation in 8 in., per cent	29.2	32.4	26-in., 160-lb. Girder Beam[b]	24.8	6 by 6 by $\frac{3}{8}$-in. Angle[a]	32.9

[a] Series No. 271.
[b] Series No. 281.

TABLE XV.—EFFECT OF THICKNESS OF SHAPE AND COMPOSITION ON YIELD POINT.

Shape and Location of Specimens		Weight	Yield Point, lb. per sq. in. Drop-of-Beam Method			Ratio, Annealed to Normal Specimens	Carbon, per cent	Manganese, per cent	Excess Yield Point of Light Shape over Heavy Shape, per cent			Excess Carbon in Heavy Shapes, per cent	Excess Manganese in Heavy Shapes, per cent
			Cooperating Laboratory Tests		Mill Tests				Cooperating Laboratory Tests		Mill Tests		
			SERIES No. 271										
Plate, Edge	Light	12 by $\frac{3}{8}$ in.	36 415		37 210	....	0.16	0.43	12		4	0.05	0.09
	Heavy	12 by $\frac{7}{8}$ in.	32 510		35 900	....	0.20	0.52					
Angle, Toe	Light	6 by 6 by $\frac{3}{8}$ in.	37 805		38 960	....	0.20	0.45	19		11	−0.04	−0.05
	Heavy	6 by 6 by $\frac{7}{8}$ in.	31 850		34 660	....	0.16	0.40					
Channel, Web	Light	15 in., 35 lb.	34 460		37 470	....	0.15	0.40	14		−1	0.06	−0.01
	Heavy	15 in., 55 lb.	30 250		37 965	....	0.21	0.39					
I-Beam, Web	Light	24 in., 79.9 lb.	34 130		36 580	....	0.20	0.50	11		−1	0.05	−0.14
	Heavy	24 in., 100 lb.	30 745		37 060	....	0.25	0.36					
			SERIES No. 281										
			Normal and Gagged	Annealed					Normal and Gagged	Annealed			
Plate, Edge	Light	$\frac{3}{8}$ in.	34 010	29 200	36 290	0.859	0.14[a]	0.39[a]	8	−2	7	0.03	0.00
	Heavy	$\frac{7}{8}$ in.	31 620	29 835	33 910	0.943	0.17[a]	0.39[a]					
Angle, Toe	Light	$\frac{1}{2}$ in.	34 110	28 025	35 280	0.822	0.18[a]	0.39[a]	−3	−8	−15	0.03	0.03
	Heavy	1 in.	35 270	30 550	40 510	0.866	0.21[a]	0.42[a]					
Girder Beam, Web	Light	24 in., 70 lb.	32 250	30 440	36 910	0.944	0.19[a]	0.49[a]	−10	+3	−12	−0.02	0.10
	Heavy	26 in., 160 lb.	35 850	29 640	42 030	0.827	0.17[a]	0.59[a]					
H-Column, Web	Light	14 in., 84 lb.	37 675	....	43 785	....	0.17[a]	0.63[a]	14	....	17	−0.01	0.01
	Heavy	14 in., 288.5 lb.	32 960	....	36 380	....	0.16[a]	0.64[a]					

[a] **Normal and gagged.**

the 15-in., 55-lb. channel to a maximum of 38,880 lb. per sq. in. for the 6 by 6 by $\frac{3}{8}$-in. angle. Basing comparisons on the grand weighted mean properties of the shapes tested, Table XIV shows the average yield point, tensile strength and elongation for all shapes, also the highest and lowest values and the range based on the minimum permitted by the specifications. Attention is directed to the range in the grand weighted mean yield point, 31 per cent. Based on weighted mean yield point, 32 per cent of the 56 portions of shape tested were within 5 per cent of the average 33,803 lb. per sq. in. and 64 per cent were within the range 30,000 to 35,000 lb. per sq. in.

TABLE XVI.—COMPARISON OF YIELD POINTS AND TENSILE STRENGTHS IN TENSION FROM MILL TESTS WITH SIMILAR DATA OBTAINED FROM COOPERATING LABORATORY TESTS—SERIES NO. 281.

Shape	Speed of Head at Yield Point, in. per minute		Heat Number	Number of Portions[a]	Number of Specimens Tested[a]	Yield Point, lb. per sq. in.			Tensile Strength, lb. per sq. in.		
	Mill Tests	Cooperating Tests				Results of Cooperating Laboratory Tests	Results of Mill Tests	Ratio, Mill Tests to Cooperating Laboratory Tests	Results of Cooperating Laboratory Tests	Results of Mill Tests	Ratio, Mill Tests to Cooperating Laboratory Tests
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
$\frac{3}{8}$-in. Plate	0.5	0.5	16 636	4	12	33 700	36 290	1.08	54 400	57 550	1.06
			25 602	4[b]	4[b]	33 230	.....	1.09	53 490	.....	1.08
$\frac{7}{8}$-in. Plate	0.5	0.5	19 603	4	12	30 930	33 910	1.10	55 210	56 610	1.03
			21 664	4[b]	4[b]	30 570	.....	1.11	54 715	.....	1.04
8 by 8 by $\frac{1}{2}$-in. Angle	0.5	0.5	24 571	4	12	37 870	35 280	0.93	59 260	58 260	0.98
			920 365	4[b]	8[b]	34 110	.....	1.03	56 920	.....	1.02
8 by 8 by 1-in. Angle	0.5	0.5	18 416	4	12	36 430	40 510	1.11	60 060	63 500	1.06
			22 591	4[b]	8[b]	35 270	.....	1.15	56 850	.....	1.12
24-in., 70-lb. Girder Beam	0.5	0.05	21 676	4	36	31 530	36 920	1.17	56 910	60 600	1.07
			24 631	4[b]	4[b]	32 250	.....	1.15	56 775	.....	1.07
26-in., 160-lb. Girder Beam	0.5	0.05	32J 002	4	36	31 775	42 040	1.32	56 190	62 600	1.11
			41J 002	4[b]	4[b]	35 850	.....	1.17	58 170	.....	1.08
14-in., 84-lb. H-Column	0.25	0.06	31H 606	4	36	35 160	43 780	1.24	59 340	64 600	1.09
			43H 539	4[b]	4[b]	37 675	.....	1.16	60 120	.....	1.08
14-in., 288.5-lb. H-Column	0.25	0.06	32H 532	4	36	31 160	36 380	1.17	57 580	62 970	1.09
			41H 454	4[b]	4[b]	32 960	.....	1.10	58 085	.....	1.08

[a] Numbers apply to tests made in cooperating laboratories.
[b] Tests made on representative specimens. For location see Table XII.

Effect of Thickness of Shape on Yield Point:

The data given in Table XV show that in the cooperating laboratory tests the average yield point of the light shape of a given type exceeded the yield point of the heavy shape of that type for every shape except the girder beam. In that case the evidence seems to indicate that the heavy girder beams were finished at a lower temperature than the light girder beams.

In contrast to the foregoing, the data for the annealed 8-in. angles of Series No. 282 reflect the influence of excess carbon and manganese in the superiority of the annealed yield point of the heavy angle over the light angle, but the excess was not manifested in the data for the normal specimens. This discrepancy was probably due to finishing the light angles at a lower rolling temperature than that used for the heavier section.

Comparison of Mill Tests with Cooperating Laboratory Tests:

A comparison of the tensile strength data obtained in the routine mill tests with the data secured by the cooperating laboratories in Series No. 281 is made in Table XVI. Two sets of comparisons are presented using two different bases from the cooperating laboratory tests. The upper set for each shape represents the average of the weighted mean values for that shape, the lower represents the average of the values obtained from the tests of a single representative specimen from each shape. The representative specimens being taken from locations similar to the locations used at the mills, the comparisons based on them show less variation than the comparisons based on the weighted mean values.

On the basis of representative specimens the average yield point for a shape by mill test exceeds the value from cooperating laboratory tests from 3 to 17 per cent and the average tensile strength by mill test exceeds the tensile strength from the cooperating laboratory tests from 3 to 12 per cent. These differences are too large to be materially reduced by certain differences in speed at yield point, columns 2 and 3 in Table XVI. If comparison is made on the basis of the average weighted mean values for whole shapes, the discrepancies between mill and cooperating laboratory test values is still more disconcerting; see columns 9 and 12, Table XVI.

The conclusion appears to be that the mill tests as conducted did not accurately represent the yield point or the tensile strength of the structural shapes rolled from a given heat. Furthermore, the data indicate that the practice of using a web specimen to represent a large, heavy I-beam, girder beam or H-column is misleading.

CONCLUSIONS

1. The tests reported herein indicate that contact with skids during cooling has little effect on tensile properties.

2. In the majority of the comparisons made, gagging of the girder beams and H-columns produced a slight increase in yield

point which for practical purposes is negligible. Other tensile properties were unaffected by gagging.

3. The location of the test specimen in shapes other than plates is of much importance, since inequalities in cooling and rolling and, in some cases, segregation produce marked differences in the yield points and smaller variations in the ultimate strengths. For large, heavy girder beam and H-column shapes a single specimen does not well represent the entire shape. For such shapes the average yield point for three specimens—intermediate flange, root, and web—is a more reliable index of the yield point of the shape. From the tests made it appears that, when it is necessary to rely on a single specimen to represent a given shape, specimens located as follows are the most representative:

SHAPE	LOCATION OF SPECIMEN
Plate	Intermediate
Angle	Intermediate
Channel	Center of Web
I-beam	Center of Web
Girder beam	Intermediate flange
H-Column	Intermediate flange

4. The tests on the annealed specimens of Series No. 281 and results of chemical analyses indicate that in most cases the variation in yield point and ultimate strength of the unannealed specimens was due to variations in cooling and rolling conditions.

5. The average ratio of drop-of-beam yield point to tensile strength for the structural shapes of these tests was 0.59. The range in minimum values based on individual whole shapes was 0.49 to 0.64 and the range in mean ratios was 0.51 to 0.66. Since only 48 per cent of the 56 individual shapes tested had ratios of yield point to tensile strength within ± 5 per cent of the mean, it is not possible to predict with accuracy the yield point from the tensile strength.

6. The range of variation in yield point of the individual portions of a given shape was in most cases small, but the range among the individual portions of all shapes from 29,090 to 38,880 lb. per sq. in. is large considering the thicknesses of the shapes tested.

The range of variation in tensile strengths of individual portions of shapes was materially less than the range of variation in yield point.

7. In six out of eight pairs of shapes tested, the yield point of the light shapes exceeded the yield point of the heavy shapes from 11 to 19 per cent. In two pairs of shapes, the yield points of the heavy shapes exceeded somewhat those of the light shapes. In one case this difference could be attributed to difference in composition.

8. In these tests lack of agreement between yield points for a given heat determined in mill tests and yield points determined in cooperating laboratory tests and between tensile strengths for a given heat determined in mill tests and tensile strengths determined in cooperating laboratory tests is apparent in the failure of several shapes to pass specification requirements in the cooperating laboratory tests and in the many discrepancies between yield points and between tensile strengths.

Acknowledgments.—The committee is pleased to acknowledge the cooperation of the Bethlehem Steel Co. and the Illinois Steel Co. in providing specimens and in conducting chemical analyses. Credit is due the laboratory staffs of the cooperating laboratories for the conduct of the tests.

This report has been submitted to letter ballot of the committee which consists of 8 members; 7 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

M. O. WITHEY,
Chairman.

REPORT OF COMMITTEE A-2
ON
WROUGHT IRON

During the past year Committee A-2 on Wrought Iron held one meeting in Detroit, Mich., on March 18, 1930. A second meeting will be held prior to the presentation of this report to the Society at which the report will be reviewed and other matters considered.

The present membership of the committee is 56, of which 26 are classed as producers, 24 as consumers and 6 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards are presented first in summarized form, together with an analysis of the letter ballot on each item. They are then referred to, where necessary, under subcommittee activities, being grouped for convenience in the order of the respective subcommittees responsible for them. The recommended revisions are given in detail in Appendix I to this report.

Proposed Revisions in Standards.—The committee recommends that the revisions in the following standards be submitted to letter ballot of the Society for adoption as standard. The revisions are divided into two groups, as follows:

Group A.—Revisions proposed in the following standards at the 1928 and 1929 annual meetings and now recommended for adoption by letter ballot of the Society:

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 27);[1]

Standard Specifications for Welded Wrought-Iron Pipe (A 72 - 27);[1]

Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 - 27);[1]

Standard Specifications for Hollow Rolled Staybolt Iron (A 86 - 27).[1]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, pp. 855–857 (1929); also 1929 Book of A.S.T.M. Tentative Standards, pp. 809–811.

Group B.—Revisions in the following standards, which are given in full in Appendix I to this report, proposed now for the first time, which the committee recommends be referred to letter ballot of the Society by the necessary nine-tenths vote of the annual meeting for immediate adoption:

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27);[1]
Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 27);[1]
Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27);[1]
Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 27);[1]
Standard Specifications for Refined Wrought-Iron Bars (A 41 – 18);[1]
Standard Specifications for Wrought-Iron Plates (A 42 – 18);[1]
Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 24);[1]
Standard Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 27).[1]

Advancement of Tentative Standard to Standard.—The committee recommends that the Tentative Specifications for Iron and Steel Chain (A 56 – 28 T)[2] be revised as indicated in Appendix I to this report, and that the specifications, as revised, be advanced to standard.

The above recommendations have been referred to letter ballot of the committee, which consists of 56 members. The analysis of the vote of the committee is given in Table I.

ACTIVITIES OF SUBCOMMITTEES

In the following, the committee discusses the foregoing recommendations in detail where necessary, as well as other features of its work, in the order of the respective subcommittees responsible for them.

Subcommittee I on Tubes and Pipe (G. H. Woodroffe, chairman).—The subcommittee is recommending certain changes in wording to clarify the intent of various sections in the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27) and in the Standard Specifications for Welded Wrought-

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[1] 1927 Book of A.S.T.M. Standards, Part I, pp. 242, 377, 381, 386, 389, 397, 400, 410.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 697 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 42.

Iron Pipe (A 72 – 27). The revisions in the latter specifications also include three important changes, including (*a*) elimination of references to the process of manufacture and the addition of a reference to a new definition for wrought iron, (*b*) revision of Table II on Weights and Dimensions to show actual thicknesses of wrought-iron pipe instead of the thicknesses of steel pipe and (*c*) revision of the section covering tension tests which will make mandatory the testing of pipe in full section for sizes up to and including 2 in. in nominal diameter.

Since the Standard Specifications A 83 include requirements for steel boiler tubes as well as wrought-iron boiler tubes, the proposed revisions have been submitted to Committee A-1 on Steel for approval.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS IN STANDARDS			
Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27)	36	0	6
Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 27)	35	0	7
Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27)	40	0	2
Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 27)	36	0	6
Standard Specifications for Refined Wrought-Iron Bars (A 41 – 18)	38	0	4
Standard Specifications for Wrought-Iron Plates (A 42 – 18)	36	0	6
Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 24)	36	0	6
Standard Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 27)	37	1	4
II. TENTATIVE SPECIFICATIONS ADVANCED TO STANDARD			
Tentative Specifications for Iron and Steel Chain (A 56 – 28 T), as revised	35	1	6
III. TENTATIVE REVISIONS OF STANDARDS ADVANCED TO STANDARD			
Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 – 27)	36	1	5
Standard Specifications for Welded Wrought-Iron Pipe (A 72 – 27)	35	1	6
Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27)	40	0	2
Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 27)	37	0	5

Subcommittee II on Merchant Bar Iron (J. B. Young, chairman).—This subcommittee is recommending a change in the process clause of the Standard Specifications for Refined Wrought-Iron Bars (A 41 – 18), involving the elimination of any reference to the process of manufacture, and is adding a reference to the proposed definition for wrought iron.

Subcommittee III on Staybolt and Engine-Bolt Iron (E. J. Edwards, chairman).—The subcommittee is recommending a revision in the process clause of the Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27), which will eliminate reference to "puddling" or any process of manufacture, but will refer to the proposed definition for wrought iron.

Subcommittee IV on Plates and Shapes.—The subcommittee is recommending a revision in the process clause of the Standard Specifications for Wrought-Iron Plates (A 42 – 18) which will eliminate the reference to any particular process of manufacture but will refer to the proposed definition for wrought iron.

Subcommittee V on Chain Iron and Iron Chain (F. M. Waring, chairman).—This subcommittee is recommending a revision in the process clause of the Tentative Specifications for Iron and Steel Chain (A 56 – 28 T), which will eliminate the reference to any particular process of manufacture of wrought iron but will refer to the proposed definition for wrought iron. An increase in the phosphorus and sulfur content of steel chain and a change in the method of sampling for check analysis are also proposed. With these revisions the specifications are recommended for advancement to standard.

Since the specifications cover iron and steel chain and since the revisions recommended in these specifications affect requirements for steel chain, these revisions have been submitted to Committee A-1 on Steel for approval.

Subcommittee VI on Wrought-Iron Blooms and Forgings (H. E. Smith, chairman).—The subcommittee is recommending a revision of the process clause of the Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 – 24). The revision will omit the present reference to puddling or any process of manufacture and will refer to the proposed definition for wrought iron.

Subcommittee VII on Nomenclature and Definitions (J. B. Young, chairman).—This subcommittee is recommending the adoption of a definition for "wrought iron" to be added to the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 27). It is also recommending the deletion of the present definition for "puddling" from this standard. At the 1929 annual meeting, Committee A-2 instructed Subcommittee VII to prepare a definition for "wrought iron" which should make reference to no process of manufacture. The recommended definition is in accordance with these instructions.

Subcommittee X on Research (H. W. Faus, chairman).—For several years this subcommittee has been engaged in an investigation of the effect of phosphorus on staybolt iron. This investigation has been carried on by a section of the subcommittee under the chairmanship of J. H. Higgins. The report on this investigation appears as Appendix II to this report and is presented as valuable information on this subject.

The Subcommittee on Research is preparing a symposium on what constitutes "quality" in wrought iron, which is expected to form an important part of the report of Committee A-2 for 1931. There is little, if any, published information on this subject and it is believed that the results of the subcommittee's efforts will be of interest and of value to the industry in general.

The resignation of the following members of Committee A-2, during the year, is announced with regret:

Mr. W. H. Hughes of Hughes & Patterson.
Mr. C. C. Osterhout, Rome Iron Mills, Inc.
Mr. C. B. Shoemaker, 2d, Glasgow Iron Co.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 56 members; 42 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

H. W. Faus,
Chairman.

G. H. Woodroffe,
Secretary.

Editorial Note

The proposed immediate revisions of the Standard Specifications tor Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes; for Welded Wrought-Iron Pipe; for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars; for Hollow Rolled Staybolt Iron; for Refined Wrought-Iron Bars; for Wrought-Iron Plates; for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars; and of the Standard Definitions of Terms Relating to Wrought-Iron Specifications were approved at the annual meeting by a unanimous vote and were subsequently adopted by letter ballot of the Society on September 2, 1930. The standards in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 238, 430, 435, 441, 444, 452, 455 and 464, respectively.

The Tentative Specifications for Iron and Steel Chain, to supersede the present standard specifications, were approved at the annual meeting and were subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, page 459.

The tentative revisions of the Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes; for Welded Wrought-Iron Pipe; for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars; and for Hollow Rolled Staybolt Iron were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 238, 430, 435 and 441, respectively.

APPENDIX I

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR WROUGHT IRON

In this appendix are given proposed revisions in certain standards and tentative standards. In connection with each title is given the reference to the publication in which the specifications appear in their present form.

PROPOSED REVISIONS IN STANDARDS

Recommended for Immediate Adoption as Standard:

Standard Specifications for Lap-Welded and Seamless Steel and Lap-Welded Iron Boiler Tubes (A 83 - 27)[1]*:*

Section 4 (b).—Change to read as follows by the addition of the italicized word and the omission of the words in brackets:

> (b) If the analysis of [only one] *either* tube does not conform to the requirements specified, analyses of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

Section 13.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

> 13. If the results of the physical tests of [only one tube] *either of the tubes, selected for physical test* [from any lot] do not conform to the requirements specified in Sections 6, 7 and 8, retests of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

Section 16 (a).—There was a tentative revision of this section recommended last year.[2] It is now recommended that the expression in this revision which reads "shall not vary more than" be changed to read "shall not be more than." It is also recommended that this section be renumbered as Section 15 (*b*). With the inclusion of these recommendations this section would then be changed from its present form: namely,

> 16. (*a*) Finished tubes 4 in. or under in outside diameter shall be circular within 0.02 in. and the mean outside diameter shall not vary more than 0.015 in. from the size ordered. For tubes over 4 in. in outside diameter, these variations shall not exceed 0.5 per cent of the outside diameter.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 242.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 109 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 809.

to read as follows:

(*b*) The outside diameter of finished tubes shall not be more than $\frac{1}{64}$ in. over the size ordered. For finished tubes up to and including 4 in. in outside diameter, the outside diameter shall not be more than $\frac{1}{32}$ in. under the size ordered and for tubes over 4 in. in outside diameter, the outside diameter shall not be more than $\frac{3}{64}$ in. under the size ordered.

Reletter Paragraphs (*b*), (*c*), (*d*), (*e*) and (*f*) of Section 16 as Paragraphs (*c*), (*d*), (*e*), (*f*) and (*g*) of Section 15, and renumber the remaining sections accordingly.

Standard Specifications for Welded Wrought-Iron Pipe (A 72-27):[1]

Section 3 (a).—Change from its present form: namely,

3. (*a*) The iron shall be made from muck bars, made from all pig puddled iron, free from any admixture of iron scrap or steel.

to read as follows:

3. (*a*) The pipe shall be made from wrought iron[a] and shall be free from any admixture of iron scrap or steel.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Section 6.—Change by the addition of the italicized words and the omission of of the word in brackets, to read as follows:

6. [All] *Each length of* pipe shall be tested at the mill to the hydrostatic pressures specified in Table I. *Pipe 2 in. and larger shall be jarred near one end while under test pressure.*

Section 10.—Change Paragraphs (*b*) and (*c*) from their present form: namely,

(*b*) Tension test specimens shall be longitudinal.
(*c*) All specimens shall be tested cold.

to read as follows:

(*b*) For pipe up to and including 2 in. in nominal size, tension test specimens shall be of the full section of the pipe. For pipe larger than 2 in. in nominal size, tension test specimens may be strips not less than $\frac{3}{4}$ in. in width, cut longitudinally from the pipe. The sides of such specimens shall be parallel and not flattened between gage marks.

(*c*) All specimens shall be tested at room temperature.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 377.

Table II.—Change the thicknesses specified in Table II for the three classifications "Standard Weight," "Extra Strong" and "Double Extra Strong" pipe to show the actual thicknesses of wrought-iron pipe necessary to obtain the weights specified. Also change the last phrase in the note at the bottom of the table, which reads, "on the basis of 1 cu. in. of steel weighing 0.2833 lb." to read "on the basis of 1 cu. in. of wrought iron weighing 0.2776 lb." The thicknesses given in the table at present are those of steel pipe. The thickness columns in Table II as revised will read as follows:

SIZE (NOMINAL INSIDE DIAMETER), IN.	THICKNESS, IN.		
	"STANDARD WEIGHT" PIPE	"EXTRA STRONG" PIPE	"DOUBLE EXTRA STRONG" PIPE
⅛	0.070	0.098	.....
¼	0.090	0.122	.....
⅜	0.093	0.129	.....
½	0.111	0.151	0.307
¾	0.115	0.157	0.318
1	0.136	0.183	0.369
1¼	0.143	0.195	0.393
1½	0.148	0.204	0.411
2	0.158	0.223	0.447
2½	0.208	0.282	0.567
3	0.221	0.306	0.615
3½	0.231	0.325	0.651
4	0.242	0.344	0.690
5	0.263	0.383	0.768
6	0.286	0.441	0.884
8	0.283	.....	0.895
8	0.329	0.510	.....
10	0.284	.....	.....
10	0.313	.....	.....
10	0.372	0.510	.....
12	0.336	.....	.....
12	0.382	0.510	.....

Section 17 (b).—Change to read as follows by the addition of the italicized words:

(*b*) Extra strong *and double extra strong* pipe shall be furnished with plain ends.

Standard Specifications for Staybolt, Engine-Bolt and Extra-Refined Wrought-Iron Bars (A 84 – 27):[1]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 381.

2. GRADE A.—The [iron] *bars* shall be rolled from a bloom, slab pile or box pile made [wholly] from reworked [all-pig puddled] *wrought* iron[a] or reworked knobbled charcoal iron. The original [puddled] *muck* or knobbled [bar] *bars* shall be twice piled and rerolled. All bars shall be the full length of the piles. The [puddle mixture] *wrought iron* and the component parts of the bloom, slab pile or box pile, shall be free from any admixture of iron scrap or steel.

GRADES B AND C.—The [iron] *bars* shall be made [wholly] from [all-pig puddled] *wrought* iron[a] and shall be free from any admixture of iron scrap or steel.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Standard Specifications for Hollow Rolled Staybolt Iron (A 86 – 27):[1]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

1. The [iron] *bars* shall be rolled from a bloom, slab pile or box pile made [wholly] from reworked [puddled pig] *wrought* iron[a] or reworked knobbled charcoal iron. The [puddle mixture] *wrought iron* and the component parts of the bloom, slab pile or box pile, shall be free from any admixture of iron scrap or steel.

---

[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Standard Specifications for Refined Wrought-Iron Bars (A 41 – 18):[2]

Section 1.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

1. [Refined wrought-iron] *The* bars shall be made [wholly] from [puddled] *wrought* iron[a] and may consist either of *all* new [muck-bar] iron or a mixture of *new* [muck-bar] iron and scrap, but shall be free from any admixture of steel.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Standard Specifications for Wrought-Iron Plates (A 42 – 18):[3]

Section 2.—Change Paragraphs (*b*) and (*c*) to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 386.

[2] *Ibid.*, p. 389.

[3] *Ibid.*, p. 397.

(*b*) Piles for Class A plates shall be made from [puddled bars made wholly from pig iron] ***wrought iron***[a] and such scrap as [emanates] ***results*** from rolling the plates.

(*c*) Piles for Class B plates shall be made from [puddle bars made wholly from pig iron or from a mixture of pig iron and cast-iron scrap] ***wrought iron***[a] together with wrought-iron scrap.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Standard Definitions of Terms Relating to Wrought-Iron Specifications (A 81 - 27):[1]

Puddling.—Delete the present definition for Puddling reading as follows:

Puddling.—The process of making wrought iron by oxidizing and removing most of the silicon, carbon, manganese and phosphorus contained in pig iron in a reverberatory furnace. "Puddling" formerly was applied only to the practice of employing refined pig iron and "Pig Boiling" was the name applied when unrefined pig iron was used, but now this distinction is not generally made as the pig iron is seldom refined. Puddling as practiced today is really pig boiling.

New Definition.—Add the following definition for Wrought Iron:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Standard Specifications for Wrought-Iron Rolled or Forged Blooms and Forgings for Locomotives and Cars (A 73 - 24):[2]

Section 2.—Change Paragraphs (*a*) and (*b*) to read as follows by the addition of the italicized words and the omission of those in brackets:

2. (a) Class A.—Blooms and forgings of class A shall be made [wholly from puddled pig-iron. The puddle mixture and the component parts of the piles from which the blooms and forgings are made] *from wrought iron*[a] *and* shall be free from any admixture of iron scrap or steel. The term "iron scrap" applies only to foreign or bought scrap and does not include the manufacturer's own scrap from the same product and of equal quality.

(b) Class B.—Blooms and forgings of class B shall be made from selected No. 1 wrought-iron scrap or a mixture of such scrap and [the puddled] *wrought iron*[a] [described in Paragraph (a)].

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 410.

[2] *Ibid.*, p. 400.

PROPOSED REVISION OF TENTATIVE STANDARD

Tentative Specifications for Iron and Steel Chain (A 56 – 28 T):[1]

Section 2.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

2. The material entering into the two classes of chain shall be as follows:

CRANE CHAIN.—[Wrought iron which] *Crane chain* shall be made from [all pig puddled] *wrought* iron[a] free from any admixture of iron scrap or steel.

NOTE.—The term "iron scrap" applies only to foreign or bought scrap and does not include local mill products of crane chain iron quality.

PROOF COIL.—[Wrought iron or open-hearth steel. The wrought iron] *Proof coil* may be made from *open-hearth steel or* all reworked scrap.

NOTE.—The term "reworked scrap" applies to steel and iron scrap, or a mixture of both.

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[a] Wrought iron is defined as follows in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A.S.T.M. Designation: A 81) of the American Society for Testing Materials:

Wrought Iron.—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

Section 4.—In the table change the requirements for phosphorus and sulfur in Steel Proof Coil to read as follows by the addition of the italicized figures and the omission of those in brackets:

	STEEL PROOF COIL
Phosphorus, maximum, per cent..........................	[0.04] *0.05*
Sulfur, maximum, per cent..............................	[0.04] *0.05*

Section 5 (b) Check analysis.—Change from its present form: namely,

(*b*) Samples for analysis shall be taken with a drill the diameter of which is approximately one-half the diameter of the bar from which the drillings are taken, and the borings shall be taken through the bar from surface to surface.

to read as follows:

(*b*) Drillings for analysis shall be taken from the entire cross-section of the bar.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 697 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 42.

APPENDIX II

INVESTIGATION OF THE EFFECT OF PHOSPHORUS IN WROUGHT IRON

By J. H. Higgins[1]

This paper summarizes an extensive series of tests carried out by a section of Subcommittee X on Research to determine the effect of phosphorus in wrought iron.

The deduction to be drawn from the test data is to the effect that tensile strength and yield point are increased, and that the elongation and reduction of area are decreased with an increase in the phosphorus content.

The vibratory tests also show an increase in vibrations before failure as the phosphorus increases; this is at variance with general expectation and opinion, and may necessitate additional tests for clarification.

Material.—Material for this investigation was furnished by two manufacturers designated as manufacturer No. 1 and manufacturer No. 2, and consisted of four lots of 6 bars each from manufacturer No. 1 and seven lots of 6 bars each from manufacturer No. 2, making a total of 66 bars. The iron was of staybolt quality, box piled, 1 in. in diameter by approximately 17 ft. in length.

Each lot of bars was assigned a lot number for indentification. Chemical analyses of each lot were made and tabulated as follows according to the increasing amount of total phosphorus. Detail results of the chemical analyses are shown in Tables I and II and the average results in Table III.

	Lot	Total Phosphorus, Per Cent
Manufacturer No. 1	No. 1	0.059
	No. 2	0.092
	No. 3	0.118
	No. 4	0.209
Manufacturer No. 2	No. 11	0.076
	No. 222	0.191
	No. 22	0.256
	No. 333	0.314
	No. 33	0.318
	No. 444	0.334
	No. 44	0.452

Heat-Treatment.—One half of each of the bars was annealed at 1600° F. for 1 hour, after being slowly heated to that temperature. The closed furnace was allowed to cool to 600° F. before the bars were removed.

Test lengths were cut from the unannealed and the annealed portion of each bar. The unannealed specimens are designated "*U*" and the annealed specimens "*A*" immediately following the lot number. Following this identifying letter, each bar was stamped with a number (1, 2, 3, 4, 5 or 6) to identify the particular bar in each lot from which the specimen was taken.

Physical Tests.—Specimens 18 in. in length from each bar in the unannealed and the annealed condition were submitted to laboratory A for chemical analyses and physical tests and a like number of specimens were submitted to laboratory B for physical tests only. Results of the chemical and physical tests are shown in Table I for the material supplied by manufacturer No. 1 and in Table II for the material supplied by manufacturer No. 2.

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[1] Materials Engineer, Camden Forge Co., Camden, N. J.

Specimens 25 in. in length from each annealed and each unannealed bar were subjected to the vibratory test under a load of 5500 lb. per sq. in., and a deflection of $\frac{3}{32}$-in. in 9 in. Detail results of these tests are given in Tables I and II and the average results are given in Table IV.

The results of the tensile strength, yield point, elongation and reduction of area tests have been plotted against the average phosphorus content in Fig. 1 for material furnished by manufacturer No. 1 and in Fig. 2 for material furnished by manufacturer No. 2. Figure 3 shows the effect of the average phosphorus content on the vibratory test.

The effect of varying percentages of total phosphorus on the physical properties is shown in Figs. 4, 5 and 6.

The findings are presented merely as information obtained by recognized test methods. No definite conclusions have been drawn and no recommendations regarding the use of high phosphorus material in service have been made.

The curves and data confirm the opinion generally held that tensile strength and yield point are increased and that the elongation and reduction of area are decreased with an increase of phosphorus content. It is also observed that the number of vibrations before failure increased with the phosphorus content. The results of the vibratory test do not confirm the experience of the users of wrought iron in service where ductility is considered of great importance, although they do confirm the results of H. F. Moore's investigation[1] of the fatigue of metals, in which he found that the endurance limit of wrought ferrous metals was a function of the tensile strength rather than of ductility.

The theory has been advanced that the ability of certain metals to recover during idle or rest periods, following repeated stresses, is an important factor in service life and some maintain that wrought iron has particular merit in this respect. If the ability of metal to recover varies directly with the ductility, the superior performance of lower phosphorus wrought irons in actual service may be thus explained.

The vibratory test, used in this investigation, subjected the metal to stresses caused by continuous oscillations of one end of the specimen, the other end being held rigidly. There was no rest or recovery period, as there usually is in service, and the higher phosphorus irons (increased tensile and lower ductility) withstood a greater number of vibrations than the low phosphorus irons (lower tensile and higher ductility). The committee offers this possible explanation of the seeming inconsistency between the results of these vibratory tests and the results obtained in service.

Acknowledgment.—Acknowledgment is made to the Logan Iron and Steel Co., of Burnham, Pa., and the Reading Iron Co., of Reading, Pa., for their assistance in this work by furnishing the material for the tests.

Acknowledgment is also made to the New York Central Lines and the Camden Forge Co. Laboratories for their chemical and physical analyses and to the American Locomotive Co. Laboratory for the vibratory tests.

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[1] H. F. Moore, "An Investigation of the Fatigue of Metals," Univ. of Illinois *Bulletin No. 136*, May 14, 1923.

TABLE I.—RESULTS OF TESTS ON EFFECT OF PHOSPHORUS IN WROUGHT IRON, MATERIAL FROM MANUFACTURER NO. 1.

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
1U1	A	0.03	0.03	0.059	0.031	0.028	0.012	0.122	31 400	45 950	31.0	52.4	½ cup	13 300
1U1	B								32 550	46 870	31.9	54.1	½ “	12 100
1A1	A								30 020	42 040	32.0	54.9	½ “	12 400
1A1	B								27 400	42 870	32.6	55.2	½ “	8 640
1U2	A	0.02	0.03	0.061	0.032	0.029	0.015	0.095	31 100	46 070	31.5	55.0	½ “	11 640
1U2	B								32 650	46 340	34.4	55.0	½ “	10 880
1A2	A								31 350	41 050	35.5	58.1	½ “	11 640
1A2	B								26 260	42 000	31.2	52.4	½ “	14 490
1U3	A	0.02	0.03	0.059	0.032	0.027	0.014	0.141	29 940	45 890	31.0	56.7	½ “	7 600
1U3	B								32 560	46 650	32.5	52.7	½ “	8 620
1A3	A								29 480	41 980	32.0	56.0	¾ “	12 920
1A3	B								26 000	42 400	32.0	54.6	½ “	9 590
1U4	A	0.03	0.03	0.058	0.031	0.027	0.013	0.135	31 450	46 400	30.5	54.3	½ “	5 680
1U4	B								31 310	47 360	33.1	55.4	¾ “	9 250
1A4	A								29 600	42 260	33.5	55.6	¾ “	17 450
1A4	B								30 760	42 770	32.9	55.3	¾ “	11 010
1U5	A	0.02	0.03	0.059	0.033	0.026	0.014	0.134	31 190	45 930	33.5	55.5	½ “	7 460
1U5	B								30 830	46 790	34.4	55.4	½ “	10 150
1A5	A								29 240	41 430	33.0	56.6	¾ “	11 060
1A5	B								31 840	42 620	34.0	56.0	¾ “	16 470
1U6	A	0.02	0.03	0.058	0.030	0.028	0.012	0.127	30 870	46 130	32.0	54.1	¾ “	12 940
1U6	B								32 250	47 410	35.6	54.6	¾ “	10 850
1A6	A								28 750	41 770	34.5	56.4	½ “	12 080
1A6	B								30 120	42 780	33.9	54.8	½ “	13 100
2U1	A	0.03	0.04	0.091	0.047	0.044	0.015	0.148	32 780	48 130	30.5	50.1	¾ “	11 440
2U1	B								34 120	48 860	30.6	50.0	½ “	10 830
2A1	A								30 910	43 150	30.0	51.5	¾ “	11 890
2A1	B								35 310	44 240	31.9	53.7	¾ “	11 750
2U2	A	0.03	0.04	0.089	0.048	0.041	0.016	0.156	32 440	47 930	31.0	49.4	¾ “	12 420
2U2	B								33 410	48 720	32.8	51.5	¾ “	12 680
2A2	A								29 240	42 630	32.0	54.7	½ “	10 400
2A2	B								31 890	43 870	34.6	54.1	½ “	9 070

[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

TABLE I (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
2U3	A	0.03	0.04	0.091	0.049	0.042	0.014	0.157	33 650	48 200	31.5	50.8	$\frac{3}{4}$ cup	10 190
2U3	B								35 700	49 100	27.2	49.1	$\frac{1}{2}$ “	11 540
2A3	A								29 480	43 090	33.0	51.4	$\frac{1}{2}$ “	6 190
2A3	B								33 580	43 850	26.0	49.0	$\frac{1}{2}$ “	8 990
2U4	A	0.04	0.04	0.092	0.049	0.043	0.015	0.159	33 430	48 200	30.5	49.1	$\frac{3}{4}$ “	9 790
2U4	B								36 250	48 890	31.9	50.3	$\frac{3}{4}$ “	9 650
2A4	A								30 760	43 580	31.0	52.8	$\frac{1}{2}$ “	11 030
2A4	B								33 280	43 910	30.6	53.2	$\frac{1}{2}$ “	15 810
2U5	A	0.03	0.04	0.096	0.046	0.050	0.014	0.165	33 060	48 410	29.0	51.3	$\frac{1}{2}$ “	10 920
2U5	B								32 510	48 950	30.6	49.7	$\frac{1}{2}$ “	13 170
2A5	A								29 370	43 240	33.0	53.6	$\frac{1}{2}$ “	10 700
2A5	B								30 890	44 010	26.2	51.0	$\frac{3}{4}$ “	9 620
2U6	A	0.03	0.04	0.094	0.049	0.045	0.016	0.169	31 840	48 430	29.5	51.8	....	14 710
2U6	B								33 140	49 220	32.5	50.5	$\frac{3}{4}$ “	13 250
2A6	A								31 890	43 860	30.5	49.5	Irreg.	10 560
2A6	B								31 190	44 340	31.0	54.2	$\frac{3}{4}$ cup	8 250
3U1	A	0.01	0.04	0.114	0.059	0.055	0.015	0.163	33 390	48 630	30.5	49.6	$\frac{1}{2}$ “	7 730
3U1	B								35 900	49 350	31.0	48.6	$\frac{1}{2}$ ‘	9 480
3A1	A								30 460	42 320	31.0	52.3	$\frac{1}{2}$ “	6 620
3A1	B								30 410	43 400	31.2	52.0	$\frac{1}{2}$ “	5 800
3U2	A	0.02	0.04	0.118	0.063	0.055	0.015	0.153	31 880	47 360	30.0	48.9	$\frac{1}{2}$ “	4 610
3U2	B								32 930	48 100	31.5	49.3	$\frac{1}{2}$ “	9 030
3A2	A								31 640	42 800	32.5	51.6	$\frac{3}{4}$ “	6 440
3A2	B								31 050	43 090	31.1	51.7	$\frac{3}{4}$ “	7 750
3U3	A	0.02	0.04	0.118	0.062	0.056	0.016	0.168	32 400	48 620	29.0	47.9	$\frac{1}{2}$ ‘	7 240
3U3	B								34 230	49 240	28.1	48.1	$\frac{1}{2}$ “	10 880
3A3	A								30 920	43 040	32.0	51.8	$\frac{3}{4}$ “	9 110
3A3	B								30 500	42 790	31.2	52.9	$\frac{1}{2}$ “	8 570
3U4	A	0.01	0.04	0.117	0.063	0.054	0.015	0.155	31 510	47 150	30.5	45.8	$\frac{3}{4}$ “	10 570
3U4	B								31 120	46 640	31.5	49.1	$\frac{1}{2}$ “	9 310
3A4	A								27 930	41 480	32.0	53.4	$\frac{1}{2}$ “	6 860
3A4	B								31 560	42 550	32.9	53.2	$\frac{1}{2}$ “	8 290

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

TABLE I (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point ½ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
3U5	A	0.01	0.04	0.117	0.060	0.057	0.015	0.150	31 910	47 830	31.0	48.7	½ cup	8 790
3U5	B								34 040	48 570	31.9	48.4	½ "	9 790
3A5	A								29 550	41 200	34.5	45.2	½ "	8 260
3A5	B								30 540	42 610	31.2	52.6	½ "	7 140
3U6	A	0.02	0.04	0.123	0.062	0.061	0.016	0.143	33 310	48 840	29.5	48.2	¾ "	10 080
3U6	B								35 220	48 900	29.4	47.1	¾ "	8 250
3A6	A								29 230	42 070	32.0	53.1	¾ "	7 610
3A6	B								30 030	42 760	32.5	52.5	¾ "	7 999
4U1	A	0.02	0.04	0.208	0.104	0.104	0.021	0.253	33 990	51 380	27.5	44.1	¾ cup	13 200
4U1	B								34 880	51 970	28.1	44.0	½ "	16 220
4A1	A								30 120	47 010	30.0	47.8	½ "	10 400
4A1	B								28 480	47 490	28.9	44.1	¾ "	7 940
4U2	A	0.02	0.04	0.204	0.111	0.093	0.021	0.263	34 180	50 600	27.0	45.9	¾ "	14 070
4U2	B								34 570	51 670	29.4	43.3	½ "	[c]
4A2	A								28 700	47 500	28.0	46.3	½ "	17 250
4A2	B								33 900	48 290	30.4	47.1	¾ "	23 290
4U3	A	0.02	0.04	0.217	0.102	0.115	0.020	0.227	32 850	50 700	30.0	41.4	½ "	19 310
4U3	B								34 230	51 440	28.7	42.0	½ "	11 560
4A3	A								27 790	47 210	29.0	45.2	½ "	12 500
4A3	B								29 400	48 200	31.2	42.2	½ "	15 310
4U4	A	0.01	0.04	0.198	0.105	0.093	0.020	0.223	34 100	50 600	28.5	42.5	½ "	11 540
4U4	B								33 390	50 900	28.7	40.9	½ "	7 600
4A4	A								28 820	46 040	27.5	31.5	½ "	19 300
4A4	B								29 890	47 640	22.8	32.6	End break	7 536
4U5	A	0.01	0.04	0.223	0.112	0.111	0.020	0.255	33 610	50 770	27.0	46.9	¾ cup	11 330
4U5	B								34 980	51 890	26.9	43.9	½ "	12 440
4A5	A								29 180	47 240	30.5	45.2	½ "	6 246
4A5	B								30 000	47 900	30.0	40.2	½ "	9 890
4U6	A	0.01	0.04	0.205	0.103	0.102	0.020	0.257	34 170	50 980	27.0	45.6	¾ "	16 040
4U6	B								35 410	52 070	29.5	44.4	½ "	15 690
4A6	A								30 460	47 100	27.5	47.7	.....	13 720
4A6	B								31 390	48 600	31.2	48.0	¾ "	15 640

[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

[c] Bent in tightening.

TABLE II.—RESULTS OF TESTS ON EFFECT OF PHOSPHORUS IN WROUGHT IRON, MATERIAL FROM MANUFACTURER NO. 2.

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
11U1	A	0.02	0.02	0.074	0.037	0.037	0.009	0.182	30 490	46 320	29.0	47.8	½ cup	8 780
11U1	B								33 540	47 110	29.8	49.5	½ "	8 620
11A1	A								31 660	43 560	35.5	54.2	½ "	10 220
11A1	B								31 600	43 910	30.5	53.1	½ "	11 480
11U2	A	0.02	0.02	0.073	0.036	0.037	0.011	0.158	29 270	44 530	30.5	52.7	¾ "	9 270
11U2	B								33 620	46 290	31.2	52.2	¾ "	8 920
11A2	A								31 410	42 970	31.5	53.6	½ "	12 960
11A2	B								31 640	44 120	31.9	53.8	½ "	14 970
11U3	A	0.01	0.02	0.071	0.035	0.036	0.011	0.179	30 970	45 210	30.0	53.3	¾ ‘	8 140
11U3	B								34 770	46 160	34.4	54.0	¾ "	10 920
11A3	A								31 150	42 390	32.5	53.6	½ "	14 300
11A3	B								31 450	43 410	31.5	54.6	¾ "	18 920
11U4	A	0.02	0.02	0.074	0.038	0.036	0.011	0.185	32 500	47 200	28.0	50.4	¾ "	11 370
11U4	B								35 080	48 010	28.7	50.8	½ "	11 180
11A4	A								30 060	43 190	33.0	53.5	.....	13 270
11A4	B								31 060	43 920	32.0	53.8	¾ "	9 980
11U5	A	0.01	0.03	0.093	0.046	0.047	0.010	0.181	32 050	47 360	29.0	50.3	¾ "	9 280
11U5	B								34 550	48 690	31.6	50.7	¾ "	9 850
11A5	A								31 410	43 690	31.5	52.6	½ "	18 540
11A5	B								31 510	42 850	30.9	52.7	½ "	13 440
11U6	A	0.02	0.02	0.074	0.037	0.037	0.010	0.165	31 600	45 300	29.5	49.6	¾ "	5 410
11U6	B								34 610	46 530	31.9	49.1	¾ "	5 470
11A6	A								30 870	42 730	31.0	52.3	½ "	11 280
11A6	B								31 810	44 190	31.9	54.2	¾ "	12 130
22U1	A	0.01	0.04	0.051	0.110	0.141	0.016	0.174	33 850	52 190	25.0	41.1	¾ "	11 790
22U1	B								33 830	52 080	31.0	42.6	½ "	19 920
22A1	A								30 580	47 190	26.0	39.8	Irreg.	18 310
22A1	B								31 840	48 730	28.1	41.7	"	24 360
22U2	A	0.01	0.03	0.258	0.135	0.123	0.017	0.192	34 400	51 850	26.0	41.4	¾ cup	28 680
22U2	B								35 300	52 250	28.5	40.9	Irreg.	13 690
22A2	A								33 440	49 270	28.0	39.5	½ cup	18 760
22A2	B								32 650	48 970	28.5	41.4	Irreg.	27 820

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

TABLE II (*Continued*)

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
22U3	A	0.01	0.04	0.263	0.134	0.129	0.016	0.188	34 460	51 580	21.0	32.0	Irreg.	14 520
22U3	B								34 770	52 220	30.5	40.6	"	13 510
22A3	A								32 460	48 050	28.0	44.1	cup	21 270
22A3	B								32 760	49 060	30.2	44.7	½ cup	22 450
22U4	A	0.02	0.04	0.255	0.124	0.131	0.016	0.195	33 020	51 630	24.0	34.8	Irreg.	19 030
22U4	B								34 790	51 600	26.0	35.8	"	12 710
22A4	A								32 970	48 660	27.0	41.9	¾ cup	13 520
22A4	B								32 310	48 460	28.1	45.5	½ "	24 390
22U5	A	0.01	0.04	0.255	0.123	0.132	0.016	0.193	34 250	51 940	25.5	39.4	½ "	12 510
22U5	B								34 830	52 220	27.7	40.4	½ "	11 940
22A5	A								31 940	48 000	30.5	45.9	½ "	28 670
22A5	B								33 960	49 550	25.0	49.5	½ "	23 700
22U6	A	0.02	0.03	0.253	0.127	0.126	0.016	0.184	33 920	52 060	26.5	41.2	¾ "	13 260
22U6	B								34 460	51 940	29.7	43.4	½ "	12 510
22A6	A								32 950	49 230	27.0	37.7	½ "	15 140
22A6	B								33 460	49 490	29.5	43.9	½ "	20 450
33U1	A	0.02	0.03	0.318	0.168	0.150	0.019	0.163	34 420	54 330	25.0	37.9	¾ "	17 150
33U1	B								37 240	54 920	27.0	36.5	½ "	11 150
33A1	A								34 140	51 170	28.0	41.3	½ "	27 520
33A1	B								32 509	52 120	29.0	42.8	½ "	23 560
33U2	A	0.01	0.03	0.322	0.176	0.146	0.018	0.148	35 710	54 610	26.0	40.9	½ "	25 640
33U2	B								36 960	54 690	27.7	38.8	½ "	21 750
33A2	A								34 520	51 410	28.5	42.4	¾ "	28 150
33A2	B								33 790	51 830	30.2	39.5	½ "	39 770
33U3	A	0.02	0.03	0.311	0.163	0.148	0.020	0.147	36 030	54 500	27.0	43.3	¾ cup	29 830
33U3	B								37 110	54 960	28.8	43.3	½ "	39 250
33A3	A								32 560	50 300	31.0	43.6	¾ "	28 540
33A3	B								33 790	51 010	25.6	37.6	Irreg.	26 030
33U4	A	0.01	0.03	0.314	0.165	0.149	0.019	0.122	36 020	54 700	22.0	32.9	"	9 970[c]
33U4	B								36 990	54 140	20.7	30.9	Flaw	26 560
33A4	A								34 190	51 890	26.0	35.4	½ cup	26 220
33A4	B								35 069	52 180	20.2	35.1	End	45 170

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

[c] Flawed bar.

TABLE II (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
33U5	A	0.01	0.03	0.326	0.168	0.158	0.021	0.153	35 850	54 820	22.5	31.7	$\frac{1}{2}$ cup	23 240
33U5	B								37 160	54 860	25.7	37.9	$\frac{1}{2}$ "	19 230
33A5	A								34 660	51 350	19.0	33.1	$\frac{1}{2}$ "	45 070
33A5	B								33 890	50 780	23.1	34.7	$\frac{1}{2}$ "	37 110
33U6	A	0.01	0.03	0.316	0.167	0.149	0.018	0.138	35 790	54 470	27.5	41.5	$\frac{1}{2}$ "	25 330
33U6	B								36 860	54 760	29.0	39.5	.....	Spoiled
33A6	A								32 830	51 820	27.5	41.1	$\frac{1}{2}$ "	26 220
33A6	B								34 157	51 647	27.5	37.3	End	21 220
44U1	A	0.01	0.03	0.417	0.200	0.217	0.021	0.120	40 070	60 810	27.5	48.6	$\frac{3}{4}$ cup	29 400
44U1	B								41 390	61 000	29.2	47.7	$\frac{3}{4}$ "	20 250
44A1	A								38 390	59 290	28.5	41.2	$\frac{1}{2}$ "	41 500
44A1	B								38 080	58 590	29.4	46.8	$\frac{1}{2}$ "	57 130
44U2	A	0.02	0.03	0.466	0.225	0.241	0.023	0.139	39 870	61 530	27.0	47.4	$\frac{3}{4}$ cup	35 790
44U2	B								41 310	61 700	28.0	44.0	$\frac{1}{2}$ "	30 030
44A2	A								37 460	58 370	29.5	47.9	$\frac{1}{2}$ "	43 870
44A2	B								30 900	59 030	29.5	48.9	End	45 110
44U3	A	0.01	0.03	0.458	0.213	0.245	0.020	0.120	40 160	61 040	26.0	43.1	$\frac{3}{4}$ cup	35 390
44U3	B								41 060	60 990	27.5	43.0	$\frac{1}{2}$ "	23 440
44A3	A								39 180	59 750	31.0	44.9	$\frac{1}{2}$ "	34 610
44A3	B								38 230	58 780	28.5	41.9	End	41 910
44U4	A	0.01	0.03	0.445	0.216	0.229	0.022	0.120	39 110	60 800	28.0	46.4	$\frac{1}{2}$ cup	39 960
44U4	B								40 850	60 730	28.8	45.7	$\frac{1}{2}$ "	25 290
44A4	A								38 230	58 670	28.5	47.3	$\frac{3}{4}$ "	50 010
44A4	B								39 080	59 010	29.0	48.6	End	33 770
44U5	A	0.01	0.03	0.452	0.207	0.245	0.022	0.128	40 210	61 120	27.0	45.4	Irreg.	34 560
44U5	B								40 730	60 830	22.6	38.6	Flaw	32 290
44A5	A								39 170	58 570	30.0	47.2	$\frac{3}{4}$ cup	28 640
44A5	B								38 680	58 930	29.0	47.2	$\frac{1}{2}$ "	36 060
44U6	A	0.01	0.03	0.472	0.193	0.279	0.020	0.171	40 460	61 110	27.0	37.5	Irreg.	38 660
44U6	B								40 930	60 980	27.5	38.4	"	50 100[c]
44A6	A								38 690	59 150	27.0	40.3	$\frac{1}{2}$ cup	31 050
44A6	B								38 610	58 410	29.4	43.5	$\frac{1}{2}$ "	23 650

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

[c] Broke outside groove.

TABLE II (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point ½ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
222U1	A	0.01	0.04	0.193	0.100	0.093	0.019	0.204	36 950	52 840	27.5	46.8	¾ cup	11 570
222U1	B								37 010	52 500	28.7	45.7	½ '	13 060
222A1	A								33 950	49 040	31.0	48.7	½ "	10 200
222A1	B								34 220	47 780	28.4	46.3	½ "	8 210
222U2	A	0.01	0.04	0.191	0.100	0.091	0.018	0.205	36 710	52 970	27.5	44.5	¾ "	13 670
222U2	B								36 200	52 980	30.2	45.4	½ "	11 420
222A2	A								32 240	48 750	30.0	48.4	½ "	11 260
222A2	B								34 490	49 740	30.6	47.1	½ "	13 080
222U3	A	0.01	0.04	0.191	0.101	0.090	0.018	0.206	36 670	52 970	27.5	45.8	¾ "	20 130
222U3	B								37 350	53 160	29.0	45.7	¾ "	12 850
222A3	A								34 230	48 730	30.5	45.3	¾ "	11 990
222A3	B								34 790	49 560	28.8	48.4	¾ "	10 710
222U4	A	0.01	0.04	0.188	0.095	0.093	0.016	0.200	35 570	52 240	27.0	46.0	½ "	19 480
222U4	B								30 330	52 800	31.5	46.3	½ "	8 310
222A4	A								34 060	48 780	30.0	46.9	¾ "	10 190
222A4	B								34 380	49 250	29.8	46.7	½ "	15 180
222U5	A	0.01	0.04	0.193	0.097	0.096	0.018	0.211	36 700	52 490	29.0	44.8	¾ "	5 880
222U5	B								37 220	52 870	30.7	47.1	½ "	13 500
222A5	A								33 960	48 820	29.0	48.2	½ "	8 900
222A5	B								32 510	49 000	30.5	47.2	¾ "	10 500
222U6	A	0.01	0.04	0.193	0.095	0.098	0.017	0.208	36 930	52 220	28.0	45.6	¾ "	17 760
222U6	B								37 110	53 030	29.2	46.1	½ "	17 300
222A6	A								34 380	48 720	30.0	37.0	¾ "	10 100
222A6	B								35 189	49 530	28.1	44.7	½ "	12 240
333U1	A	0.01	0.03	0.305	0.156	0.149	0.020	0.170	35 150	52 540	29.5	41.9	½ "	20 140
333U1	B								35 190	52 910	28.7	42.6	½ "	26 790
333A1	A								33 280	49 350	27.0	45.3	½ "	26 160
333A1	B								32 670	49 440	27.1	41.7	½ "	15 660
333U2	A	0.01	0.03	0.313	0.164	0.149	0.019	0.186	35 100	52 460	29.0	42.3	....	11 730
333U2	B								35 710	53 070	30.2	42.7	½ "	19 700
333A2	A								34 600	50 250	29.0	44.2	½ "	19 340
333A2	B								33 330	49 500	29.0	42.3	½ "	22 300

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

TABLE II (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
333U3	A	0.01	0.03	0.307	0.160	0.147	0.020	0.160	35 310	52 690	27.5	41.8	¾ cup	16 620
333U3	B								35 730	53 440	30.2	43.2	¾ "	12 190
333A3	A								34 700	49 450	30.0	43.7	½ "	12 970
333A3	B								33 330	50 250	28.8	41.0	½ "	13 370
333U4	A	0.01	0.03	0.320	0.161	0.159	0.019	0.162	35 310	53 120	28.0	43.6	½ "	16 690
333U4	B								35 770	53 190	28.5	45.2	½ "	16 790
333A4	A								33 020	49 250	29.5	43.8	¾ "	11 020
333A4	B								33 050	50 100	28.8	45.6	½ "	12 870
333U5	A	0.01	0.04	0.325	0.177	0.148	0.018	0.221	35 620	53 020	28.5	44.1	½ "	11 190
333U5	B								35 560	53 440	30.7	41.8	½ "	18 170
333A5	A								33 500	49 520	30.0	43.2	½ "	10 730
333A5	B								33 330	50 350	28.4	44.6	½ "	11 500
333U6	A	0.01	0.03	0.312	0.157	0.155	0.018	0.195	35 590	52 760	28.0	41.4	¾ "	30 750[c]
333U6	B								35 420	53 000	29.0	44.1	¾ "	13 810
333A6	A								33 060	49 260	29.0	46.7	¾ "	12 540
333A6	B								32 280	49 580	30.2	44.1	½ "	11 750
444U1	A	0.01	0.03	0.350	0.185	0.167	0.021	0.188	37 540	54 690	25.5	42.8	½ "	36 800
444U1	B								38 240	55 710	22.5	43.9	½ "	29 230
444A1	A								33 790	51 030	28.0	46.7	½ "	23 120
444A1	B								34 750	51 770	28.1	45.6	½ "	14 060
444U2	A	0.01	0.03	0.327	0.175	0.152	0.020	0.139	37 590	55 560	28.0	44.8	½ "	18 490
444U2	B								38 150	55 890	29.3	41.8	½ "	45 550
444A2	A								33 800	51 430	30.5	44.4	¾ "	17 530
444A2	B								33 480	52 030	30.6	46.7	¾ "	18 280
444U3	A	0.01	0.03	0.335	0.165	0.170	0.019	0.152	36 890	54 940	28.0	46.5	½ "	41 370
444U3	B								38 440	55 550	28.7	45.4	½ "	19 980
444A3	A								33 870	51 890	32.0	46.9	¾ "	21 650
444A3	B								34 200	51 740	29.6	46.3	¾ "	15 150
444U4	A	0.01	0.03	0.337	0.171	0.166	0.019	0.168	38 070	55 190	26.5	44.3	¾ "	33 930
444U4	B								38 780	56 170	29.0	47.3	¾ "	39 900
444A4	A								34 590	51 990	28.0	44.9	½ "	17 190
444A4	B								32 910	52 510	30.2	43.8	½ "	20 240

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[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in

[c] Loose in grip.

TABLE II (*Continued*).

Speed of head of testing machine: Laboratory A, yield point $\frac{5}{16}$ in. per minute, tensile strength 1 in. per minute.
Laboratory B, yield point $\frac{1}{2}$ in. per minute, tensile strength 3 in. per minute.

Mark	Laboratory[a]	Chemical Analysis							Physical Properties				Fracture	Vibratory Test, Total Revolutions[b]
		Carbon, per cent	Manganese, per cent	Total Phosphorus, per cent	Phosphorus in Slag, per cent	Phosphorus in Iron (by difference), per cent	Sulfur, per cent	Silicon, per cent	Yield Point, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent		
444U5	A	0.01	0.03	0.321	0.161	0.160	0.021	0.138	38 000	55 090	26.5	45.2	$\frac{3}{4}$ cup	22 400
444U5	B								38 240	55 710	28.1	48.4	$\frac{3}{4}$ "	31 020
444A5	A								35 000	52 060	30.0	46.2	$\frac{3}{4}$ "	24 320
444A5	B								34 770	52 200	29.0	44.0	$\frac{3}{4}$ "	15 780
444U6	A	0.01	0.03	0.335	0.179	0.156	0.020	0.160	38 330	54 910	27.0	41.8	$\frac{1}{2}$ "	51 440[c]
444U6	B								38 000	55 710	30.0	44.2	$\frac{1}{2}$ "	14 180
444A6	A								35 550	51 950	29.0	48.4	$\frac{1}{2}$ "	14 700
444A6	B								34 680	52 370	30.0	42.7	$\frac{1}{2}$ "	19 270

[a] Laboratory A.—New York Central Railroad.
Laboratory B.—Camden Forge Co.

[b] Olsen Vibratory Machine. Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

[c] Broke outside groove.

TABLE III.—AVERAGE RESULTS OF CHEMICAL AND PHYSICAL TESTS.

	Lot	Mark	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 8 in., per cent	Reduction of Area, per cent	Phosphorus in Iron, per cent	Total Phosphorus, per cent
Manufacturer No. 1........	No. 1	U	46 478	31 508	32.6	54.6	0.028	0.059
		A	42 164	29 235	33.1	55.5		
	No. 2	U	48 662	33 527	30.6	50.3	0.044	0.092
		A	43 647	31 490	30.8	52.4		
	No. 3	U	48 186	33 153	30.3	47.5	0.056	0.118
		A	42 509	30 318	32.0	51.9		
	No. 4	U	51 247	34 197	27.7	43.8	0.103	0.209
		A	47 518	29 844	28.9	43.2		
Manufacturer No. 2........	No. 11	U	46 559	32 754	30.3	50.9	0.038	0.076
		A	43 328	31 303	31.0	53.5		
	No. 222	U	52 756	36 229	28.9	45.9	0.093	0.191
		A	48 957	34 033	29.8	46.3		
	No. 22	U	51 982	34 323	26.8	39.5	0.130	0.256
		A	48 755	32 610	28.0	42.9		
	No. 333	U	52 970	35 455	29.0	42.9	0.151	0.314
		A	49 692	33 346	28.9	43.9		
	No. 33	U	54 647	36 345	25.8	37.9	0.150	0.318
		A	51 459	33 842	26.3	38.7		
	No. 444	U	55 427	38 023	28.4	44.7	0.172	0.334
		A	51 914	34 283	29.6	45.6		
	No. 44	U	61 062	40 513	27.2	44.7	0.243	0.452
		A	58 880	38 439	28.9	45.5		

TABLE IV.—AVERAGE RESULTS OF VIBRATORY TESTS.

	Lot	Mark	Number of Revolutions	Phosphorus in Iron, per cent	Total Phosphorus, per cent
Manufacturer No. 1...	No. 1	U	10 039	0.028	0.059
		A	12 570		
	No. 2	U	11 716	0.044	0.092
		A	10 350		
	No. 3	U	8 813	0.056	0.118
		A	7 537		
	No. 4	U	13 546	0.103	0.209
		A	13 250		
Manufacturer No. 2...	No. 11	U	8 934	0.038	0.076
		A	13 460		
	No. 222	U	13 600	0.093	0.191
		A	11 050		
	No. 22	U	15 340	0.130	0.256
		A	21 570		
	No. 333	U	16 710	0.151	0.314
		A	15 100		
	No. 33	U	23 910	0.150	0.318
		A	31 210		
	No. 444	U	30 260	0.172	0.334
		A	38 440		
	No. 44	U	31 370	0.243	0.452
		A	38 940		

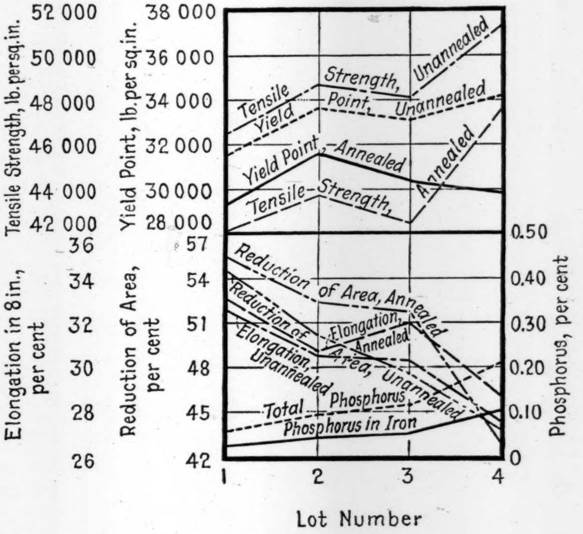

FIG. 1.—Effect on Physical Properties of Phosphorus in Wrought Iron, Material from Manufacturer No. 1.

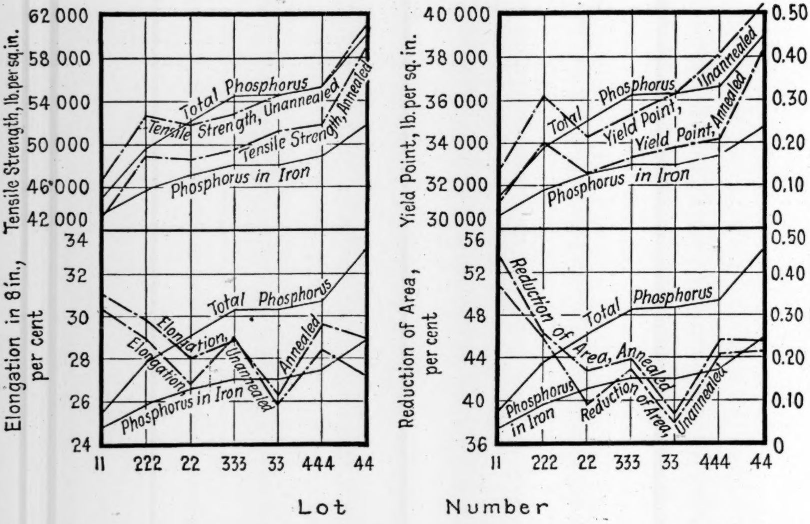

FIG. 2.—Effect on Physical Properties of Phosphorus in Wrought Iron, Material from Manufacturer No. 2.

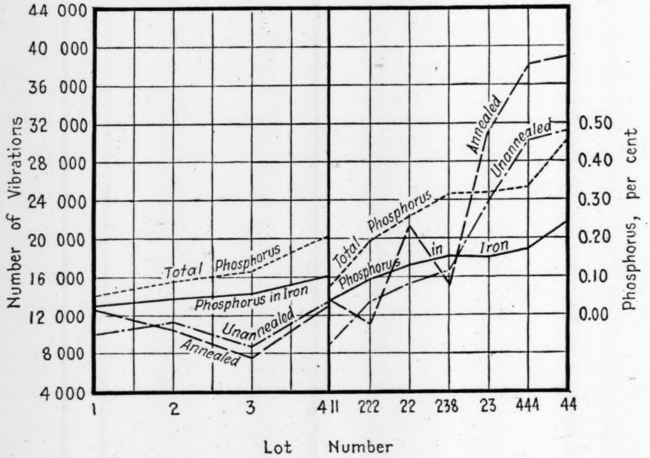

FIG. 3.—Effect of Phosphorus on the Vibratory Test of Wrought Iron.

Load 5500 lb. per sq. in., $\frac{3}{32}$ in. oscillation in 9 in.

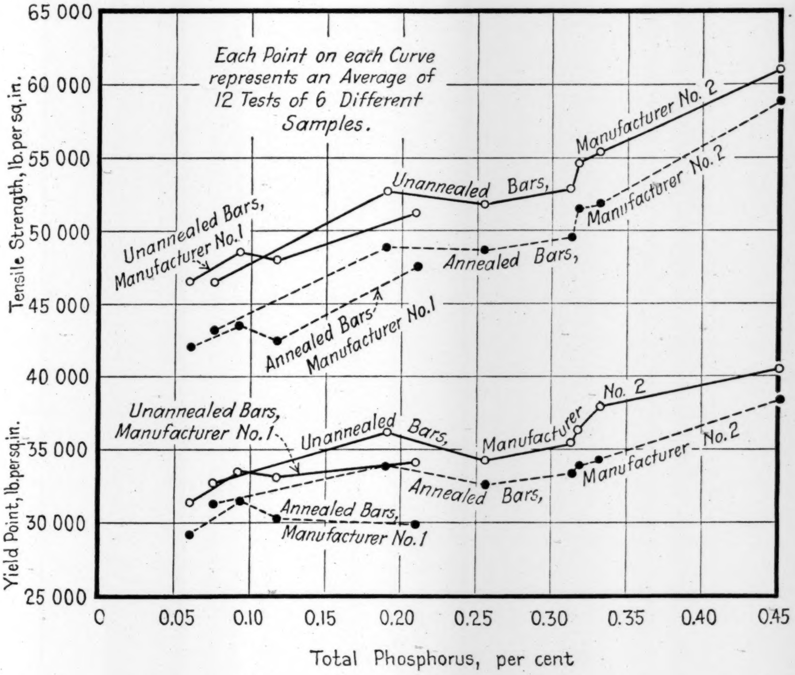

FIG. 4.—Effect of Total Phosphorus on Tensile Strength of Wrought Iron.

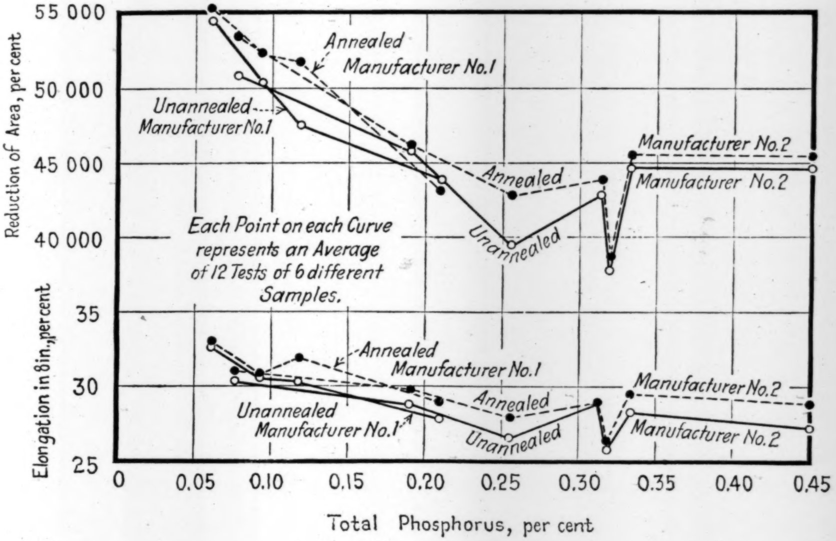

FIG. 5.—Effect of Total Phosphorus on the Ductility of Wrought Iron.

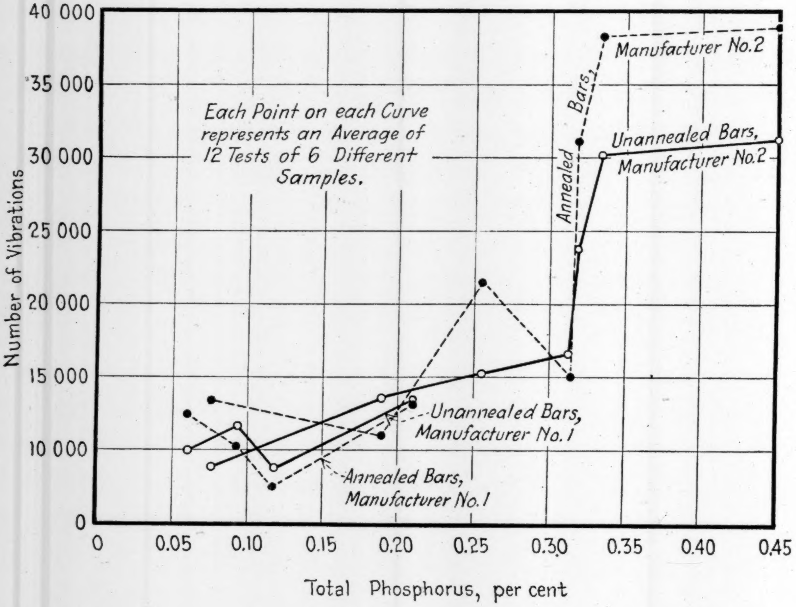

FIG. 6.—Effect of Total Phosphorus on the Vibratory Test of Wrought Iron.

REPORT OF SECTIONAL COMMITTEE ON STANDARDIZATION OF DIMENSIONS AND MATERIAL OF WROUGHT IRON AND WROUGHT STEEL PIPE AND TUBING

The Sectional Committee on Standardization of Wrought Iron and Wrought Steel Pipe and Tubing, functioning under the procedure of the American Standards Association, has no proposed standards ready this year for presentation to the sponsor bodies for approval as tentative standards or as American Standards. This report is, therefore, one of progress only.

The subgroup appointed to develop basic formulas for use in drafting schedules of wall thicknesses for all sizes of pipe to suit different operating conditions recently reported. The recommendation is for the use of a modified Barlow formula patterned after that in the Boiler Construction Code of the American Society of Mechanical Engineers, the principal departure being a factor of 0.875 by which the term "t" in the Boiler Code formula will be multiplied to compensate for commercial tolerances in pipe manufacture. Using these formulas as a base, thickness schedules will be established to suit the allowable stresses and prevailing pressures of different industries.

The recommendations of the Subgroup on Basic Formulas are now being referred to the sectional committee for approval by letter ballot. In the event of a favorable vote, the problem of developing thickness schedules will proceed. One step in this direction is already under way. Inquiries have been addressed to the different industries using pipe, asking their opinion as to satisfactory "S" values for use in the basic formulas and what operating pressures obtain in their industries. This information will be used as a basis for a new series of wall thickness schedules, based on uniform P/S relations, which are intended to supplant present inconsistent schedules such as those designated as standard weight, extra strong, etc., and which it is hoped will serve all industries using pipe made by that process.

Several requests for standards have come to the sectional committee concerning types of pipe for which no specifications were in existence at the time. Since the scope of the sectional committee's work covers the correlation of dimensional standards and material specifications it was apparent that specifications should be developed before undertaking the preparation of dimensional standards for these products. Accordingly the American Society for Testing Materials was requested to cooperate, and the actual work of preparing the specifications was assigned to Subcommittee IX on Steel Tubing and Pipe of Committee A-1 on Steel. The types of pipe in question are: fusion-welded, resistance-welded, hammer-welded, lock-bar, and riveted. Preparation of these specifications is under way, and they should be available to the sectional committee within the year, after which work on the corresponding dimensional standards can be undertaken.

Unless unforeseen difficulties are encountered, it is expected that rapid progress can be made during the coming year in carrying out the above program.

Respectfully submitted on behalf of the sectional committee,

H. H. MORGAN,
Chairman.

SABIN CROCKER,
Secretary.

REPORT OF COMMITTEE A-3

ON

CAST IRON

Since the 1929 annual meeting of the Society, Committee A-3 has held two meetings, one at Chicago, Ill., on October 7, 1929, and the other at Detroit, Mich., on March 20, 1930. A third meeting will be held prior to the presentation of this report to the Society, at which time the report will be reviewed and other matters considered.

The present membership of the committee is 84, of which 33 are classed as producers, 34 as consumers, and 17 as general interests.

At the March meeting, the committee passed the following motion with reference to listing of cast irons:

> Cast Iron shall be known and listed by classes wherever there is no application name now used; for example, pipe iron, cylinder iron, etc. Any names to describe quality shall be abandoned; for example, high-test cast iron, semisteel, etc.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 29 T).[1]—Subcommittee IV on Car Wheels (G. E. Doke, chairman) recommends that these Tentative Specifications, submitted last year as a complete revision of the Standard Specifications for Chilled Cast-Iron Wheels (A 46 – 24), be revised as follows and continued as tentative:

Section 9.—In the table under Pararaph (*a*) change the requirement for height of drop for the 850-lb. (385-kg.) wheel from "13 ft. (3.96 m.)" to "15 ft. (4.57 m.)."

Change Paragraph (*b*) to read as follows by the addition of the talicized words and the omission of those in brackets:

> (*b*) If the test [wheel cracks] *wheels crack in the plate* with three blows or less, [it] *they* shall be considered as having failed.

Standard Specifications for High-Test Gray-Iron Castings (A 88 – 29).[2]—Subcommittee XIII on High-Test Cast Iron feels that it is necessary to increase the requirements on physical properties of these specifications inasmuch as the present requirements would no longer be considered satisfactory for high-test gray-iron castings. The committee accordingly recommends the following revisions of these specifications for publication as a tentative revision:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 574 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 69.

[2] 1929 Supplement to Book of A.S.T.M. Standards, p. 71.

Section 1.—Change from its present form: namely,

1. These specifications cover all classes of gray-iron castings which are required to have a high strength, including those generally known as semi-steel castings.

to read as follows:

1. These specifications cover all classes (Note) of gray-iron castings (free from massive cementite) which conform to the minimum physical requirements specified herein.

NOTE.—These specifications cover the so-called semi-steels, pearlitic irons, special alloy irons, and any other gray irons which conform to the requirements for physical properties.

Section 2.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

2. The tension test will be made only when specified by the purchaser and at his expense.

Section 3.—Change to read as follows by the addition of the italicized words:

3. The castings may be made by the cupola, *air-furnace*, *electric-furnace*, or any other *generally* approved process. *Where heat treatment, heated molds or other expedients are utilized for modification of the properties of the casting, the equivalent of these shall be used in the preparation of test bars.*

Section 4 (a).—Change the minimum load requirement for the transverse test from "2250 lb." to "2500 lb."

Section 5.—Change to read as follows by the addition of the italicized figure and the omission of that in brackets:

5. When tension tests are specified, the tension test specimen shall show a minimum tensile strength of [28,000] *33,000* lb. per sq. in.

Tentative Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 – 29 T).[1]—Subcommittee XVII on Gray-Iron Castings for Valves, Flanges and Pipe Fittings (L. W. Spring, chairman) recommends that these tentative specifications, which have been tentative for one year, be adopted as standard. These specifications were developed and issued in 1929 as the result of a request in December, 1927, from the Sectional Committee on Pipe Flanges and Fittings, functioning under the procedure of the American Standards Association. During the year the Manufacturers' Standardization Society of the Valve and Fittings Industry, by a formal letter ballot, adopted these specifications as a standard practice. The committee therefore recommends that these specifications be adopted as standard.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 581, (1929); also 1929 Book A.S.T.M. Tentative Standards, p. 76.

The results of the letter ballot of the committee on the recommendations made in this report are given in Table I.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee XIII on High-Test Cast Iron (J. W. Bolton, chairman).—This subcommittee has drawn up a statement containing information with respect to the production of low-carbon cast iron which is appended to this report.

Subcommittee XIV on Correlation of Test Bar and Casting (R. S. MacPherran, chairman).—This subcommittee has been very active during the past year. There has been considerable discussion as to the value of the present arbitration test bar for cast iron. During the past year, some work has been done on the correlation of test bar and casting. A report by Mr. A. L. Boegehold of the General Motors Corp. on "Effect of Section Size on Physical Properties of Cast Iron" appears as Appendix I to this report. Another report by Mr. M. V. Healey of the General Electric Co., entitled "Comparison of Properties of Different Wall Sections of Cast Iron and Those of the Standard Arbitration Bar" is given in Appendix II. This latter investigation was made under the direction of Mr. J. A. Capp of this committee.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Items	Affirmative	Negative	Not Voting
I. PROPOSED TENTATIVE REVISION OF STANDARD			
Standard Specifications for High-Test Gray-Iron Castings (A 88 – 29)	49	0	3
II. PROPOSED REVISION OF TENTATIVE STANDARD			
Tentative Specifications for Chilled-Tread Cast-Iron Wheels (A 46 – 29 T)	36	0	16
III. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Tentative Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 – 29 T)	44	2	6

It is felt that the problem of correlation of test bars and the selection of the proper type of test bar is an important one in gray-iron foundry work, and the subcommittee feels that further work should be done. A number of the members of the subcommittee have promised to carry on tests with various sizes of test bars as suggested by the chairman, and report the results. This information will be available for the 1931 report of Committee A-3.

Subcommittee XV on Impact Testing (J. T. MacKenzie, chairman).—This committee has been actively engaged during the past year in planning an extensive investigation on impact testing of cast iron. Funds to the amount of $1500 have been raised among the members of the committee and a comprehensive program for impact testing and the correlation of impact and static testing of cast iron has been worked out. It is expected that this work will be carried on during the coming year so that a report can be made at the 1931 meeting of the Society.

The election of officers resulted in the selection of Hyman Bornstein, chairman; A. L. Boegehold, vice-chairman; and W. H. Rother, secretary for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 84 members; 48 members returned their ballots, of whom 47 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

HYMAN BORNSTEIN,
Chairman.

W. H. ROTHER,
Secretary.

EDITORIAL NOTE

The proposed tentative revision of the Standard Specifications for High-Test Gray-Iron Castings was accepted for publication as tentative and appears on page 1270.

The proposed revision of the Tentative Specifications for Chilled-Tread Cast-Iron Wheels was accepted. The specifications in their revised form appear on page 1271.

The Tentative Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings were approved at the annual meeting and were subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, page 499.

DISCUSSION

[Mr. H. Bornstein in presenting the report of Committee A-3 on Cast Iron recommended the advancement to standard of the Tentative Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings (A 126 - 29 T).—Ed.]

Mr. J. T. MacKenzie[1] (*presented in written form*).—The proposed specifications for valves, flanges and pipe fittings is consistent neither with the standardization program of this Society, nor with the metallurgical requirements of the material.

In 1929, the 1.2-in. diameter bar broken on 18-in. supports was made the standard for cast iron. There were two principal advantages of this length and diameter over those previously in force: First, the flexure readings are over twice as great; and second, the new bar corresponds to the equivalent bar of the British standardizing bodies, and bids fair to become an international standard. Now, for one class of material we are asked to go back to the 12-in. span; to subordinate the transverse test to the tension test, and through the implication involved in the change of molding procedure to assert that the test bar represents the casting itself, which is explicitly denied by all of our other specifications for cast iron. The specifications are a step backward toward the multiplicity of test bars which were such a nuisance to our predecessors.

Another important objection to these specifications is the phosphorus limit of 0.75 per cent, especially as applied to class A iron (21,000 lb. per sq. in. tensile strength). Forty-five per cent of the cast-iron pipe made in the United States is made in the Birmingham district, where the phosphorus hovers between 0.70 and 0.85 per cent. A large tonnage of pipe fittings is now made from this iron, and it is safe to say that no test at our disposal would show any superiority for the 0.70-per cent phosphorus fittings in comparison with those containing 0.85 per cent of phosphorus. In fact, if steel or other scrap were the means employed to reduce the phosphorus, the high-phosphorus casting probably would be the better because of the superior casting properties of the high pig-iron mix.

We request that these specifications be continued as tentative and that the cast-iron pipe interests be given adequate representation on the subcommittee having jurisdiction over these specifications. To date they have been completely ignored.

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[1] Chief Chemist, American Cast Iron Pipe Co., Birmingham, Ala.

MR. C. D. MATHEWS[1] (*presented in written form*).—This Society, in 1929, after a number of years' discussion, adopted as standard a 1.20-in. diameter transverse test bar, broken on 18-in. supports to cover the arbitration test bar. It is now proposed to adopt a bar having a different length and distance between supports and method of casting for the Specifications for Gray-Iron Castings for Valves, Flanges and Pipe Fittings.

In these specifications, two classes of iron are covered—regular gray iron with 21,000 lb. per sq. in. tensile strength, and high-strength gray iron with 30,000 lb. per sq. in. tensile strength; the tension test being specified with the transverse test optional.

Present standard specifications cover a range of regular gray-iron castings of 18,000, 21,000, and 24,000 lb. per sq. in. tensile strength and high-strength gray iron of 28,000 lb. per sq. in. tensile strength. It would seem that the class of castings covered by the proposed specification, as far as quality of iron goes, is already taken care of in the present specifications, and to adopt new specifications for 21,000 lb. per sq. in. iron and 30,000 lb. per sq. in. iron does not seem reasonable. With the transverse test optional, an additional complication is added by introducing the proposed bar and method of casting.

The question of phosphorus limit specified of not over 0.75 per cent is also objectionable. This limit would have no effect at all on the iron coming within the range of 21,000 lb. per sq. in. tensile strength and for the class of castings calling for the high-strength cast iron of 30,000 lb. per sq. in. tensile strength, this would either be obtained from a considerably lower phosphorus iron or a steel mix in combination with low phosphorus which would bring the phosphorus considerably below the limit.

MR. H. BORNSTEIN.[2]—The objections raised by Messrs. MacKenzie and Mathews are not new to Committee A-3. They were thoroughly discussed at the March meeting of the committee and at that meeting there was a pretty full attendance. After that meeting the minutes of the meeting were sent out to all the members and when this came to a vote there were only two negative votes, which I think adequately shows the sentiment of the committee in reference to these objections.

In respect to the test bar, there is no obligation upon any subcommittee in bringing in a specification to use the arbitration test bar. Mr. MacKenzie, who is here supposedly representing the pipe interests, knows that the A.S.T.M. specifications for pipe do not require the use of the arbitration test bar; they specify a test bar which is believed to give the best results on pipe. And similarly the specifications for locomotive cylinders do not specify the arbitration test bar. The arbitration test bar, just as the name indicates, is an arbitration bar and not a bar for a specific casting. As to the pipe interests being ignored, these specifications came up for consideration one year ago. The members of the Society had an opportunity at that time to voice any objections to the specifications. It was not necessary to wait until these specifications were adopted as standard by the Manufacturers' Standardization Society and were being recommended for adoption as standard by this Society before raising these objections. Subcommittee XVII was organized for the specific purpose of formulating these specifications, and I am sure, speaking as I do as chairman of Committee A-3, that had the pipe industry or Mr. MacKenzie desired representation upon the subcommittee, they could have had it at any time.

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[1] Metallurgical Engineer, United States Pipe and Foundry Co., Burlington, N. J.

[2] Director of Laboratories, Deere and Co., Moline, Ill.

MR. MACKENZIE.—Referring to the transverse test bar, I will admit that the cast-iron pipe people are using the old 2 by 1 by 24-in. bar, and up until the time of the adoption of the 18-in. supports for the new bar, there was no hope of getting us to go to a bar which was so unsatisfactory in its flexural characteristics as the old arbitration bar. At the present time there is a sectional committee at work on the revision of the specifications for cast-iron pipe, and I think it would be no trouble at all to have the new arbitration bar specified in the new specifications for cast-iron pipe, because it is fully as satisfactory as the old 2 by 1-in. bar. As to the question of opposition, I know that the secretary, or at least the former secretary of Committee A-3, had a number of letters in his file showing the opposition of the cast-iron pipe industry to these specifications, and I should like to know if these letters have been received by the present officers of that committee?

MR. L. W. SPRING.[1]—I was chairman of Subcommittee XVII which was asked by a committee of the American Standards Association to formulate specifications for cast iron for valves, flanges and pipe fittings. This subcommittee was made up, as committees should be, of producers and consumers according to the regulations of this Society.

The specification was drawn with the valves, flanges and pipe fittings industry in mind. Practically all of the people who are making valves, flanges and pipe fittings have chemical and physical testing laboratories; they make test bars not once a day or once on a job but practically every hour of the day to represent their iron all the way through, all their cupolas being run under strict chemical control. In making test bars every hour that the cupolas are running, it is necessary to have bars that can be made with reasonable convenience, that can be tested quickly and regularly, that can be numbered in the mold with figures cast on the bars themselves to designate the cupola number, day, and the hour cast.

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[1] Chief Chemist and Metallurgist, Crane Co., Chicago, Ill.

Practically all of the valves and fittings people design their valves, fittings, and flanges through Barlow's formula based on the tension test and not through a transverse test. However, a transverse bar 14 in. long and 1.2 in. square is made along with the tension test bar on the same gate from plate pattern, on a molding machine, out of the same sand as the valves and fittings. The molder numbers these in the mold, together with the date, the hour and the cupola number from which the iron will be poured. If necessary, one could take a week's bars, eight of them a day, and mix them all, and inside of fifteen minutes, a boy could have them all straight, and, after testing, one could have a record for every hour of every day of the week for every cupola. It is very desirable for this purpose that we have short bars instead of 21-in. bars and the bars of the specifications in question were designed with such in view.

Now it has been proved not only by members of this subcommittee through some years of experience, but recognized by committee A-3, that it is possible to make a tension test with the same or even greater accuracy than the transverse test. These tension test bars are designed to be threaded on the ends with the U. S. standard thread; they are pulled in self-centering shackles, thus giving at least as great accuracy as transverse bars.

It seems rather unfortunate that opposition should come up at this time to what is a matter of progress. The specifications were needed. They were asked for by a sectional committee functioning under the American Standards Association, were made in response to that request, were approved unanimously by Subcommittee XVII. It went until the March meeting of the committee before there was a negative vote cast against it. No written objections to the specification have been received by the Society.

The American Society for Testing Materials is trying to make its specifications more used. Such is very desirable and we all want to help. Here is a specification which already is used, though it has been on the books in a tentative form for only one year, has been adopted formally by the Manufacturers' Standardization Society, and several foundries are using it regularly in controlling their iron.

MR. J. W. BOLTON.[1]—I am here representing the Manufacturers' Standardization Society in this matter. This group initiated the demand for these specifications and brought them before the American Society for Testing Materials. Mr. Spring has very well outlined all the main points involved. However, there is one point to which I should like you to give consideration. After all is said and done, no matter what the technical specifications may be, the manufacturer of the material or of the article has a responsibility that must be very carefully maintained. For this reason the Manufacturers' Standardization Society has taken the point of view that although the specifications offer his customer more assurance than he had before as to the quality of the material entering into his product, the responsibility does not end there. The manufacturers themselves have given these specifications very careful study. In the case of a number of us, we worked very carefully upon them to find out whether or not we were best protecting ourselves through the protection of our customers in those cases in which limiting the danger of explosion, etc., might come up. We also were very careful to obtain directly from the engineers of our customers their reactions to these specifications. The action taken by the subcommittee was outlined by Mr. Bornstein and again by Mr. Spring, and showed there was no organized opposition to these specifications until a rather late date. The Manufacturers' Standardization Society has followed this up and adopted these specifications as standard practice. It satisfies them and has satisfied their customers, and I may say that the people with whom they have been in consultation represent by far the largest group that are interested directly in these commodities.

[The motion to adopt the specifications as recommended by Committee A-3 was carried.—Ed.]

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[1] Chief Chemist and Metallurgist, The Lukenheimer Co., Cincinnati, Ohio.

REPORT OF SUBCOMMITTEE XIII ON HIGH-TEST CAST IRON

In view of the interest in the production of cast irons giving high-strength values, the subcommittee was asked to prepare a statement giving information in respect to these irons.

Most of the higher-strength irons produced today are comparatively low in total carbon content. Because of their greater strength and usual higher modulus of elasticity and other improved mechanical properties, such metals have found useful engineering applications. When properly made they present no great difficulties in molding practice, and machine reasonably well.

Processes for producing low-carbon iron may be classified as:

1. Those starting with a very low carbon charge, to more than offset any carbon reabsorption in process; example, cupola with high steel charge.

2. Those starting with charge which may be nearly the desired carbon content and burning a small amount of the carbon out by an oxidizing atmosphere; example, air furnace.

3. Those burning out or diluting the carbons.

The usual objective is carbon 2.75 to 3.00 per cent. This can be obtained by any of the above processes. The first is limited, but can go well under the usual range if necessary. By the other two processes the carbon can be cut down to any point even into the steel casting range.

CUPOLA PROCESS

In the cupola, complete oxidation of the fuel coming to the melting zone is essential to continued operation. Also, the iron dropping down past the tuyeres is exposed to a definitely oxidizing reaction. If there is a cupola well, the metal is likely to be nearly eutectic if sufficient time is allowed. This should be avoided.

Steel scrap is low in carbon and might offer a happy solution to easy carbon reduction if it were not for the facts that the steel is partially carburized during melting operation (hot steel in contact with carbon and carbon monoxide) and the molten metal in the well also absorbs carbon as indicated above. Therefore, it is necessary to add more low-carbon material than would otherwise be the case.

Therefore, to produce low-carbon iron, high percentages of steel are used, often 60 to 95 per cent. The initial bed should be high, approximately 48 in. above the tuyeres. This is burned through, and enough fresh coke added to regain the 48-in. level before charging stock. The ratio of metal charge to coke charge usually varies between 6 to 1 and 7 to 1. An essential point is to charge early and let soak for one, and preferably two hours, leaving only the tap hole and one peephole open (this latter to prevent explosions).

A comparatively large air volume is used, about 30,000 to 37,000 cu. ft. per ton of metal melted. Fast melting and hot iron are essential to best results.

A shallow well and frequent or continuous tap favors low total carbon.

High-silicon and high-manganese materials may be added in the charge, minimizing oxidation and the chances of getting oxidized iron. Sufficient high-silicon, high-manganese and alloying elements may be added in the ladle to obtain the desired final analysis.

AIR FURNACE

Air furnaces for melting cast iron are of the reverberatory type, quite similar to those used in malleable work and in principle somewhat resembling open-hearth steel melting units. Details of construction are obtainable in any standard work on ferrous metallurgy.

During melting, silicon, carbon, and manganese are lost through oxidation. The greatest oxidation takes place when the metal commences to melt, the dripping globules offering large surfaces to the combustion products and excess air. When melted down the slag protects the metal from the gases, and any secondary reactions take place more slowly through the slag. Although carbon reduction occurs during melting, the original charge is easily adjusted in carbon content by steel addition, and excessive oxidation is not necessary.

The most desirable stock for rapid economical air furnace operation is that which presents the greatest surface in proportion to its weight. Larger scrap can be handled in this furnace than in the cupola.

The manner of placing the charge is important. All pieces should be charged so that greatest surface will be exposed to the heat. Large pieces are placed in the hottest part of the furnace. No medium or heavy pieces are placed flat on the floor but are supported by pig iron. Pig iron is stacked criss-cross. No scrap is charged closer than 6 in. to the side walls. All large pieces with flat tops are tilted so that metal can flow off readily as it melts. When all the scrap and regular pig have been charged, the high-silicon pig and spiegeleisen are distributed uniformly throughout the charge.

High-grade, long-flame, gas coal and natural draft were the most common fuels in the past. Powdered coal, gas or oil can be used. Forced draft can be used. Excess draft increases oxidation, but a small excess of oxygen promotes higher temperature and faster melting. When sufficient metal has melted to form a bath, melting can be greatly hastened by pulling the larger pieces into the bath.

OTHER PROCESSES

(*a*) The electric arc furnace has been used as a straight melting unit, somewhat like usual air furnace process. By charging enough steel the carbon can be brought to the desired low point. However, there usually is some carbon pickup as distinguished from carbon loss in the air furnace. In order to get lower current consumption so-called duplexing processes have been used. The electric furnace is charged with the steel scrap, and this melted down. Molten iron from the cupola is added and the mixture brought to the desired temperature.

(*b*) Carbon reduction is possible through ore addition. This can be done in electric-furnace or in the air-furnace type. On account of operating difficulties this method is not widely favored.

(*c*) Partial oxidation (as in the bessemer process) is another possibility. Since silicon and manganese are oxidized before the carbon, carbon reduction by this means is unlikely as a commercial proposition. The difficulty of stopping the reaction at the desired point and the necessity for resiliconizing would make operation clumsy.

(*d*) Dilution processes can be used where equipment is available. Cast iron of suitable composition is diluted in the ladle with molten steel, carbon and silicon content being reduced simultaneously. This is the basis of the Krantz process used in the production of malleable cast iron. Bessemer, open-hearth, or electric-furnace steel may be satisfactory.

Respectfully submitted on behalf of the subcommittee,

J. W. BOLTON,
Chairman.

APPENDIX I

EFFECT OF SECTION SIZE ON PHYSICAL PROPERTIES OF CAST IRON

By A. L. Boegehold[1]

Committee A-3 on Cast Iron through its Subcommittee XIV is considering the question of correlation of test bar and casting. This involves the question of the influence of casting section size and attendant cooling rate upon the physical properties of the iron. At a meeting of the Subcommittee on Correlation of Test Bar and Casting consideration was given to two methods for obtaining the influence of section size on the physical properties of cast iron. One consisted of making a square pipe casting with four sides of different thicknesses and the other involved pouring test bars of different cross-sections all from the same gate.

The author agreed to conduct some tests with the latter method.

A pattern was made up as shown in Fig. 1 for pouring six test bars all from the same gate. The test bars are of such shape that the ends may be threaded for gripping in the tension testing machine. The central part of the test bars are all 1¼ in. in width with thicknesses respectively 1¼, 1, ¾, ½, ¼ and ⅛ in. The bars with thickness of ½ in. or less in the test section were cored out in the heavy end section in order to reduce the change in section from the end section to the middle section. After casting, the test bars were machined to the shapes shown in Fig. 2. Two sides of the test section of each test bar were left as cast and the other two sides were machined enough to remove the layer of metal affected by the skin cooling. In this way a test section is obtained which is intended to simulate the condition that would exist if a flat test bar was machined out of a casting wall leaving the cast surfaces on two sides. In this way it is intended to obtain some idea of the strength of the walls of a casting as they exist in the casting. It is believed that this information is more desirable than obtaining tests on bars with the casting surface removed from all sides thereby excluding the skin cooling effect which is a factor in the strength of iron in all castings.

Figure 3 illustrates the cross-sectional area of the test bars as cast and as machined ready for testing.

This report includes results of preliminary tests made on only two kinds of iron made in an electric furnace from pig and scrap and having the following chemical compositions:

	Iron No. 1	Iron No. 2
Total Carbon, per cent	3.68	3.40
Manganese, per cent	0.49	0.67
Sulfur, per cent	0.045	0.051
Phosphorus, per cent	0.148	0.156
Nickel, per cent	0.04	1.02
Chromium, per cent	0.06	0.23
Silicon, per cent	2.30	2.20

Results of the tensile strength and Brinell hardness tests on these test bars are given in Fig. 4.

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[1] Metallurgist, General Motors Research Labs., Detroit, Mich.

The decreasing hardness with decreasing section size of test bars made of iron No. 1 is due to the presence of low combined carbon rosette formation near the surface. This phenomenon is peculiar to certain compositions and is more pronounced in thin sections; hence the decreasing hardness which is the reverse of what happens in irons that do not exhibit the rosette formation such as iron No. 2. In test bars of iron No. 2, the hardness increases with decreasing section size in the usually accepted manner.

The tensile strength results show higher strength in smaller sections and also higher strength in low-carbon irons than in high-carbon irons which is in accord with existing information on this subject.

Photomicrographs showing the structure of test bars near the edge of the cross-section at the cast surface side and also at the center of the cross-section are given in Figs. 5 and 6. The rosette structure previously mentioned in connection with iron No. 1 is well illustrated in Fig. 4.

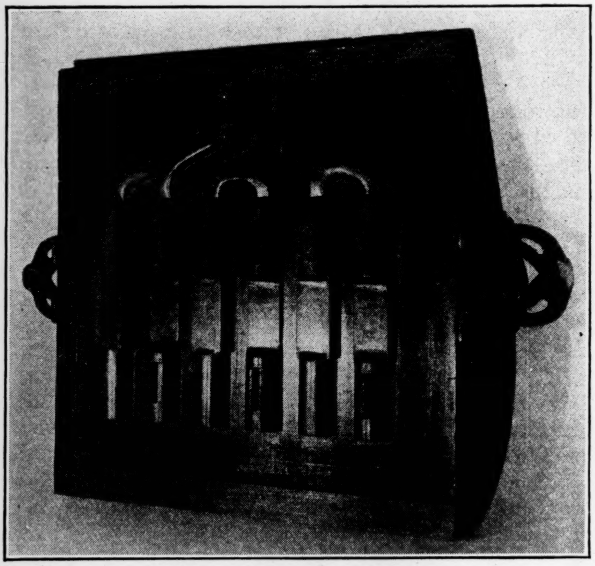


FIG. 1.—Test Bar Pattern.

As a means of determining the physical properties of iron in a casting, the use of test bars such as described in this report can be used only in an indirect way. It will not do to assume that a ¼-in. section in a casting will have the same hardness and tensile strength as a test bar ¼ in. in section. Depending on the influence of adjacent sections, a ¼-in. section in a casting will have a cooling rate which may be faster or slower than that of the test bar and consequently its hardness may be anything from that of a ⅛-in. to that of a 1¼-in. test bar. The only way that any correlation might be established between test bar and casting is to make a Brinell hardness test on the particular section of the casting in question and then assume that its tensile strength is the same as that of the test bar having the same Brinell hardness. For example, if a casting wall ¼ in. in thickness has a Brinell hardness number of 187 and is made of iron No. 2, it would be nearer right to assume that the iron in that casting wall had a tensile strength of 27,200 lb. per sq. in. which is the strength of the test bar 1¼ in. in section, than to assume its tensile strength as 33,600 lb. per sq. in. which is the strength of the test bar ¼ in. in section but which has a Brinell hardness number of 212.

This brings up the question as to whether there is a definite relation between Brinell hardness and tensile strength for a given iron composition irrespective of the size section in which that Brinell hardness occurs. If there is a definite relation between hardness and tensile strength then the Brinell hardness of the casting can be interpreted in terms of tensile strength by referring to the hardness and tensile strength of test bars made from the same iron. It is true that a Brinell hardness test on certain sections of a casting may require its destruction and if the casting is to be destroyed, tension test specimens might just as well be cut. Tension tests on specimens cut from a casting will not be accurate because the shape of the casting will, in most instances, not permit cutting a test bar of the proper shape to give an accurate tension test. The success of this type of a test then depends upon the ability to establish a relation between tensile strength and Brinell hardness for each iron composition.

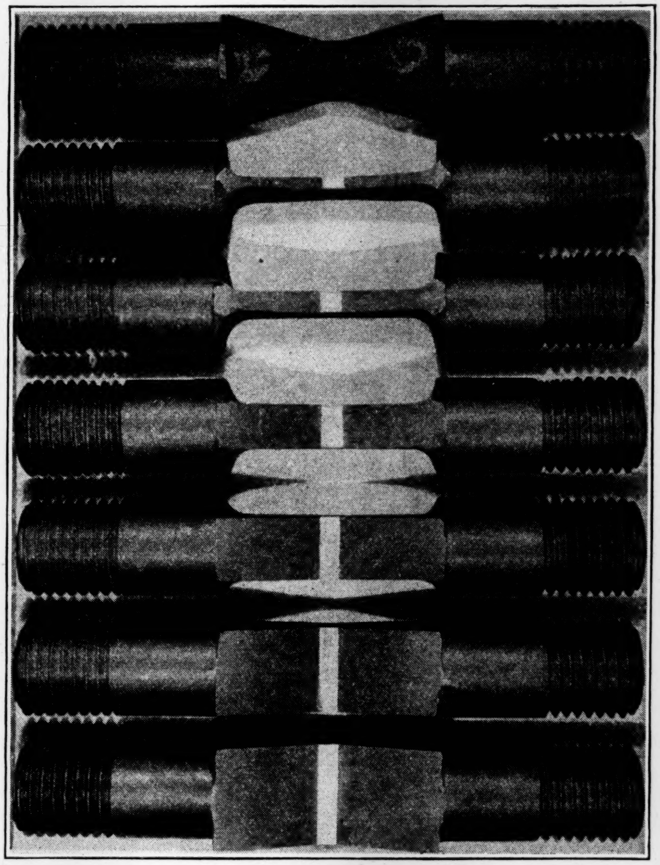
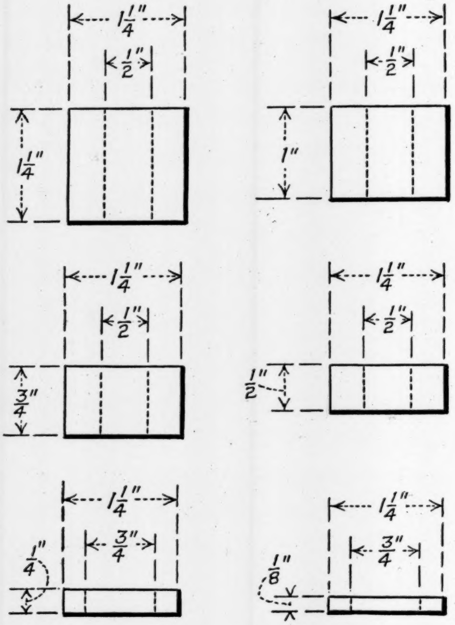


FIG. 2.—Test Bars Machined.


$1\frac{1}{4}''$
$\frac{1}{2}''$
$1\frac{1}{4}''$
$1\frac{1}{4}''$
$\frac{1}{2}''$
$1''$
$1\frac{1}{4}''$
$\frac{1}{2}''$
$\frac{3}{4}''$
$1\frac{1}{4}''$
$\frac{1}{2}''$
$\frac{1}{2}''$
$1\frac{1}{4}''$
$\frac{3}{4}''$
$\frac{1}{4}''$
$1\frac{1}{4}''$
$\frac{3}{4}''$
$\frac{1}{8}''$

Full line shows size as cast; dash line shows size as tested.
Dense structure produced by surface cooling was removed from two sides of each test bar.

FIG. 3.—Cross-Sections of Test Bars Showing Size as Cast and as Tested.

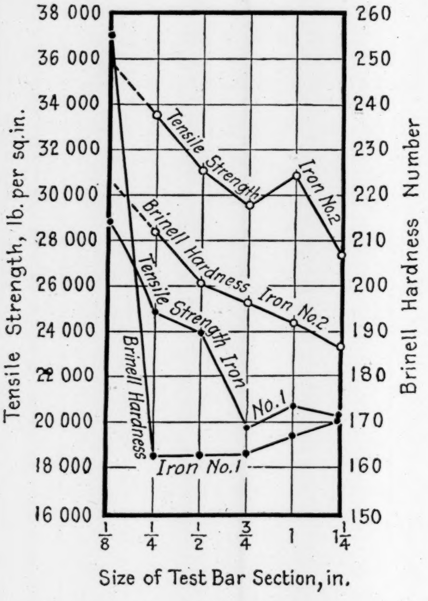
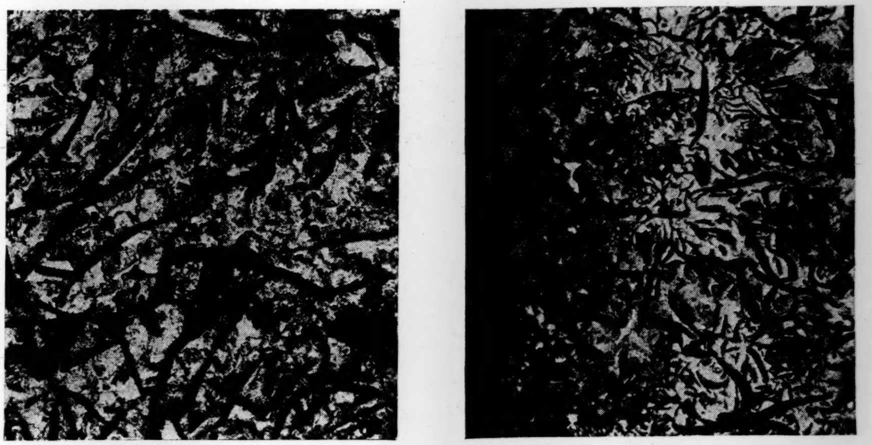
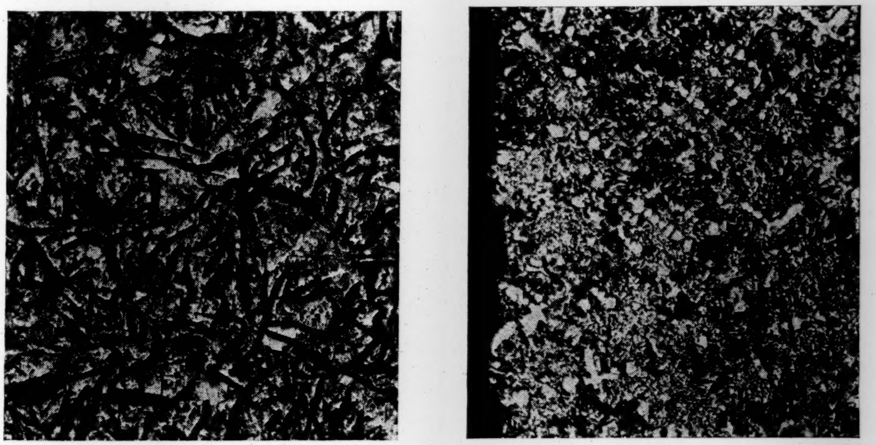


FIG. 4.—Tensile Strength and Brinell Hardness of Test Bars.

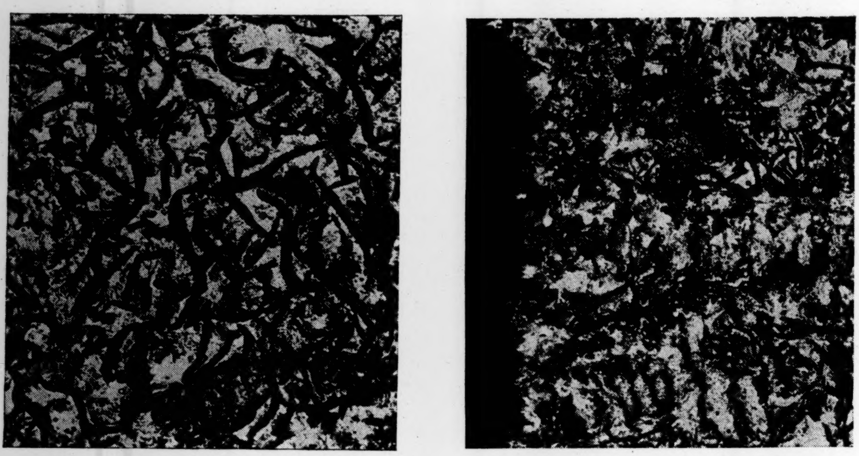


(a) $\frac{3}{4}$-in. section at the center.
(b) $\frac{3}{4}$-in. section just under the surface.

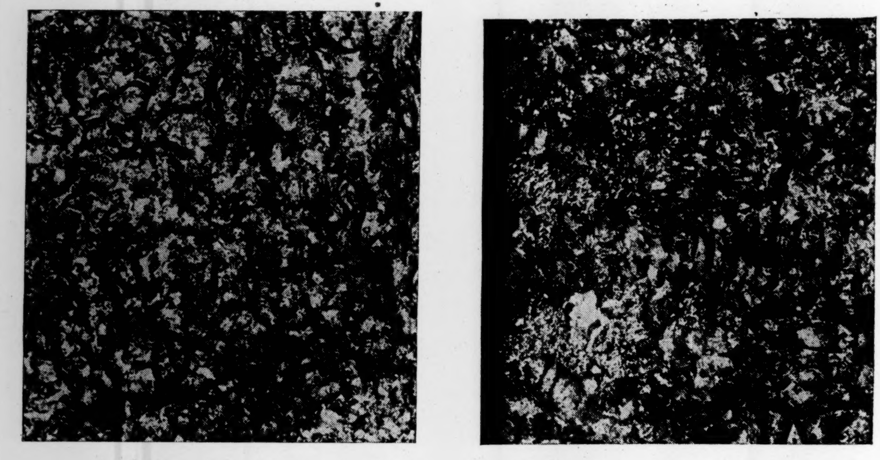


(c) $\frac{1}{4}$-in. section at the center.
(d) $\frac{1}{4}$-in. section just under the surface.

FIG. 5.—Photomicrographs of Iron No. 1, Showing Variation of Structure Caused by Cooling Rate (× 100).



(*a*) ¾-in. section at the center. (*b*) ¾-in. section just under the surface.



(*c*) ¼-in. section at the center. (*d*) ¼-in. section just under the surface.

FIG. 6.—Photomicrographs of Iron No. 2, Showing Variation of Structure Caused by Cooling Rate (× 100).

DISCUSSION

MR. H. BORNSTEIN.[1]—Referring to Mr. Boegehold's paper suggesting a means of correlation between Brinell hardness and strength of castings, we have done some work during the past year which confirms Mr. Boegehold's work. We had one particular casting that failed in service. Among the various examinations made were chemical analyses, hardness tests, transverse tests, tension tests, examinations of the fracture and microscopic examinations. We found, first, that the chemical analysis did not correlate with any of the physical tests. It did not give us a clue as to failure. We did find a very good correlation between Brinell hardness, fracture, structure, transverse strength and tensile strength.

On the basis of those few tests on failed castings, we decided to make tests on production, and for a period of 60 days we made a 100-per-cent inspection for Brinell hardness. Also, on each day's run we took three castings which were toward the high side of the Brinell range, three toward the low side and three near the average and made transverse tests on the casting as well as tension tests on a specimen cut from the casting. After that 60-day period, we were able to say that there was a definite relation between the Brinell hardness and the strength of the casting, because the correlation of test results was very good. As a result we were able to set up a specification for Brinell hardness which should assure us of a certain strength for the casting and perhaps an absence of failure under service conditions.

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[1] Director of Laboratories, Deere and Co., Moline, Ill.

APPENDIX II

COMPARISON OF THE PHYSICAL PROPERTIES OF DIFFERENT SECTIONS OF CAST IRON AND OF THE STANDARD ARBITRATION TEST BAR

By M. V. Healey[1]

The purpose of this investigation was to obtain data for a comparison of the physical properties of different wall sections of cast iron and with those of the standard arbitration test bar.

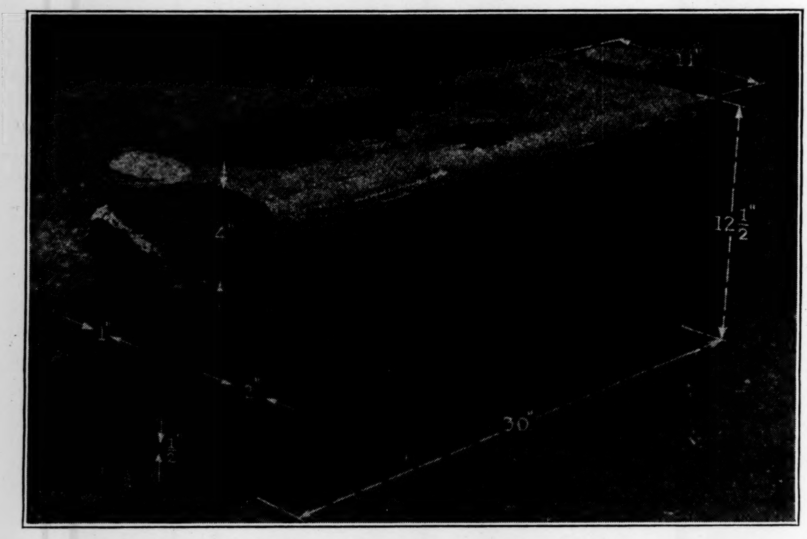

Fig. 1.—Test Casting for Providing Specimens to Determine Relation Between Properties of the Casting and Those of Standard Arbitration Test Bars.

The results indicate that an arbitration bar is harder and stronger than any section of a casting made from the same material, that a 1-in. section has better physical properties than thinner or thicker sections, and that above 1 in. the properties are inversely proportional to wall thickness.

Test Casting and Arbitration Bars.—To provide specimens for test a casting having wall thicknesses of ½, 1, 2 and 4 in. was designed. This casting was made in the shape and of the dimensions shown in Fig. 1. In order that any given test specimen taken from the casting might not be unduly affected by gates and risers, the gates and risers were placed at the ends, and a 7½-in. section was removed from each end of the casting before the test specimens were selected. Gating was accomplished by means of 1 by 2-in. openings at the upper corners of the 1-in. wall. These were fed from a common pouring basin. The position of the two 5 by 12-in. risers may be seen in the illustration.

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[1] Metallurgist, Testing Laboratory, General Electric Co., Schenectady, N. Y.

The casting was made in green sand with a dry sand core. The green sand was faced with sea coal while the dry sand core was given a coating of graphite. A pair of arbitration test bars conforming to the Standard Specifications for the Arbitration Test Bar and Tension Test Specimen for Cast Iron (A 124 - 29) of the American Society for Testing Materials,[1] were cast with the test casting in dry sand with a graphite coating.

The iron from which the casting was made is the variety used locally for making refrigerator cylinder castings. Chemical analyses are recorded later in this report.

Both the test casting and the arbitration test bars were allowed to cool before being broken out of the molds. The casting was found to be sound except for a small shrinkage area in the center of the 4-in. wall. It was possible, however, to avoid this porous section in testing.

TABLE I.—RESULTS OF FLEXURE TESTS.

		THICKNESS, IN.	WIDTH, IN.	LOAD, LB.	DEFLECTION, IN.	MODULUS OF RUPTURE, LB. PER SQ. IN.
4-in. wall	Bar No. 1......	3.87	0.978	8680	0.185	42 200
	Bar No. 2......	3.87	0.978	9500	0.188	46 100
	Bar No. 3......	3.93	0.978	9490	0.178	45 500
2-in. wall	Bar No. 1......	1.970	1.029	5670	0.167	48 900
	Bar No. 2......	1.850	0.975	4960	0.172	48 200
	Bar No. 3......	1.970	1.128	6650	0.173	47 700
1-in. wall	Bar No. 1......	1.060	1.018	2970	0.172	48 700
	Bar No. 2......	1.045	1.019	3170	0.185	52 600
	Bar No. 3......	1.075	1.000	3070	0.177	51 400
½-in. wall	Bar No. 1......	0.683	1.029	1850	0.166	46 100
	Bar No. 2......	0.720	1.006	1960	0.172	48 400
	Bar No. 3......	0.750	1.012	2210	0.176	51 800
Arbitration Bar No. 1		1.294 in. in diameter		4750	0.116	67 100
Arbitration Bar No. 2		1.297 in. in diameter		4970	0.121	69 500

Chemical Analyses.—Samples for analyses of the test casting were obtained by milling a channel across each of the four walls. The sample from the arbitration test bar was obtained by drilling the center of the bar. Results of the chemical analyses were as follows:

	TEST CASTING				ARBITRATION
	4-IN. WALL	2-IN. WALL	1-IN. WALL	½-IN. WALL	TEST BAR
Total Carbon, per cent......	2.74	2.85	2.95	3.04	3.08
Graphitic Carbon, per cent..	2.25	2.48	2.51	2.58	2.57
Combined Carbon, per cent..	0.49	0.63	0.44	0.46	0.51
Silicon, per cent............	2.04	1.95	1.96	2.01	2.19
Sulfur, per cent............	0.087	0.085	0.074	0.080	0.078
Phosphorus, per cent........	0.38	0.38	0.37	0.36	0.24
Manganese, per cent........	0.56	0.56	0.56	0.54	0.56

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[1] 1929 Supplement to Book of A.S.T.M. Standards, p. 73.

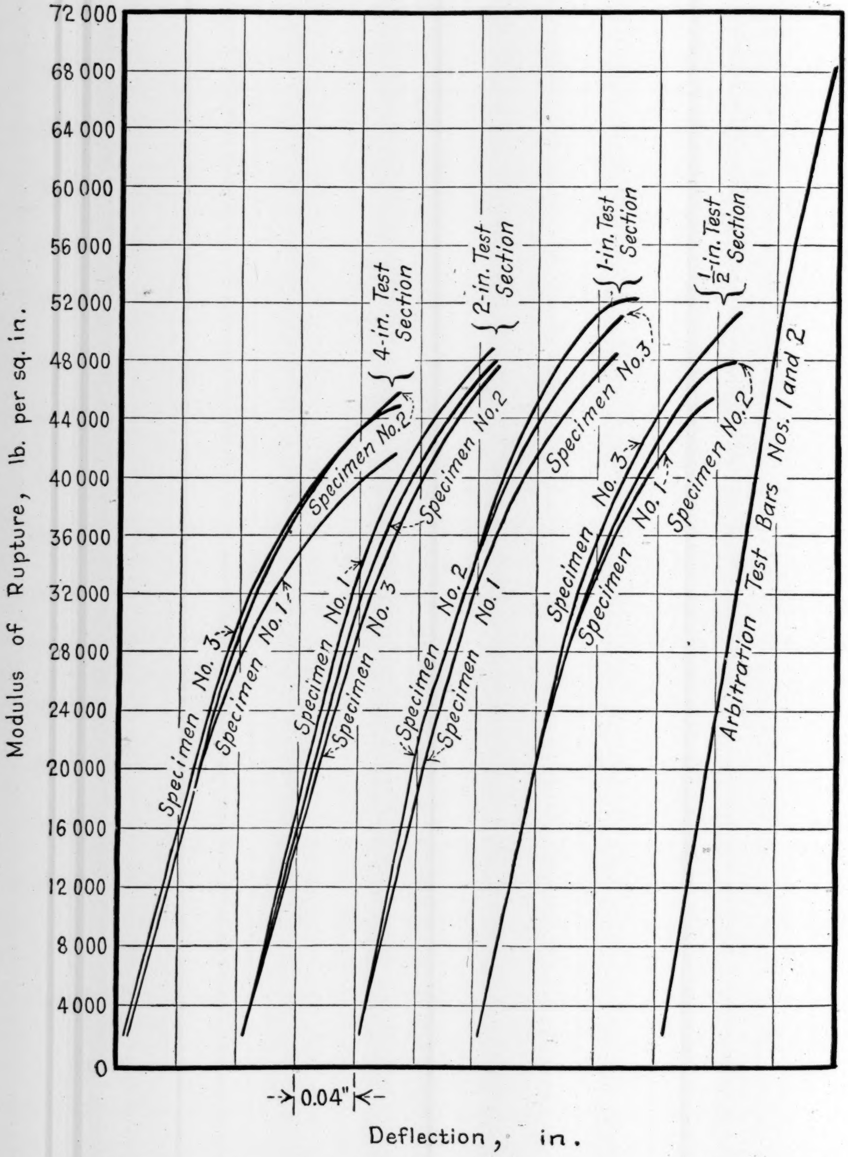


FIG. 2.—Relation Between Deflection and Modulus of Rupture of Various Test Sections and Arbitration Test Bars.

The samples for analyses were in the form of milling chips and the wide variation in results is probably due to this fact. The fine material contains more of the graphite than the coarse. Any attempt to balance the different sizes in the weighed portion taken for actual analysis is not likely to be successful. At the present time there appears to be no reliable method of sampling cast iron.

Flexure Tests.—The original 30-in. test casting was reduced to a 15-in. length by removing $7\frac{1}{2}$ in. from each end. Three 15 by 1-in. bars were then taken from each wall, the thickness of the bars being that of the walls from which they were taken. In obtaining the bars, bar No. 2 in each case was taken at the center of the 8-in. inside wall. Bars Nos. 1 and 3 were those immediately adjoining bar No. 2.

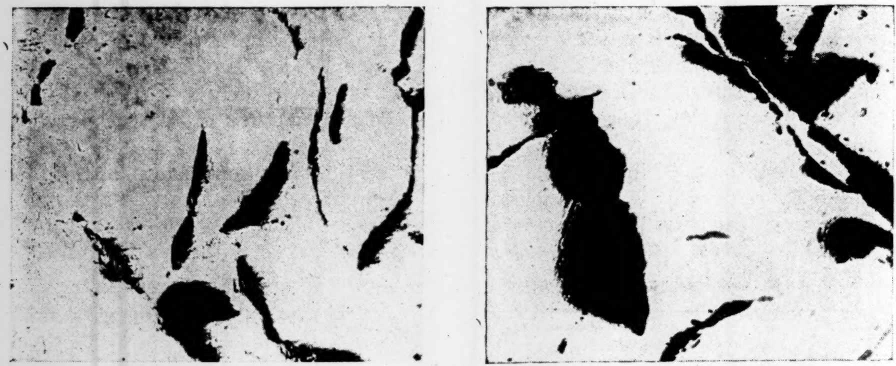
TABLE II.—RESULTS OF TENSILE STRENGTH AND BRINELL HARDNESS TESTS.

		Location of Specimen	Diameter, in.	Area, sq. in.	Tensile Strength, lb. per sq. in.	Brinell Hardness Number, 10-mm. ball, 3000-kg. load	Remarks
4-in. wall	Bar No. 1......	Center..	0.5000	0.1964	24 100	152	Broke through fillet
	Bar No. 1......	Center..	0.5020	0.1979	24 000	143	Broke through fillet
	Bar No 1......	Skin.....	0.5025	0.1983	27 700	163	
	Bar No. 1......	Skin.....	0.5040	0.1995	26 600	167	Broke through fillet
	Bar No. 2......	Center..	0.5010	0.1971	23 600	152	
	Bar No. 2......	Center..	0.5020	0.1979	23 600	149	Broke through fillet
	Bar No. 2......	Skin.....	0.5015	0.1978	26 100	170	Broke through fillet
	Bar No. 2......	Skin.....	0.5035	0.1991	28 300	163	
	Bar No. 3......	Center..	0.5010	0.1971	24 500	149	
	Bar No. 3......	Center..	0.5025	0.1983	24 900	149	
	Bar No. 3......	Skin.....	0.5020	0.1979	27 100	170	
	Bar No. 3......	Skin.....	0.5030	0.1987	27 000	163	
2-in. wall	Bar No. 1......	Center..	0.5020	0.1979	26 000	163	
	Bar No. 1......	Skin.....	0.5010	0.1971	28 600	167	Broke $\frac{1}{8}$ in. from fillet
	Bar No. 2......	Center..	0.5040	0.1995	26 600	163	
	Bar No. 2......	Skin.....	0.5245	0.2160	29 000	167	
	Bar No. 3......	Center..	0.5090	0.2035	25 500	163	
	Bar No. 3......	Skin.....	0.5050	0.2003	26 900	163	Broke through fillet
1-in. wall	Bar No. 1......	....	0.5070	0.2019	29 200	167	Broke through fillet
	Bar No. 1......	....	0.5005	0.1967	28 000	179	
	Bar No. 2......	....	0.5220	0.2140	29 800	170	
	Bar No. 2......	....	0.5050	0.2003	29 200	170	Broke through fillet
	Bar No. 3......	....	0.5040	0.1995	29 900	170	
	Bar No. 3......	....	0.4650	0.1698	29 200	170	
$\frac{1}{2}$-in. wall	Bar No 1......	....	0.5005	0.1967	29 700	163	
	Bar No. 1......	....	0.4955	0.1928	28 000	147	Fracture at surface hole
	Bar No. 2......	....	0.5010	0.1971	27 700	151	
	Bar No. 2......	....	0.5010	0.1971	29 400	156	
	Bar No. 3......	....	0.5005	0.1967	23 400	163	Broke through fillet (inclusion)
	Bar No. 3......	....	0.5010	0.1971	29 200	156	
Arbitration Test Bar.......		....	......	......	31 800	195	

Flexure tests were made between 12-in. supports, with the 1-in. dimension vertical. Elastic deflections were taken with different increments of loading and the modulus of rupture calculated from the formula:

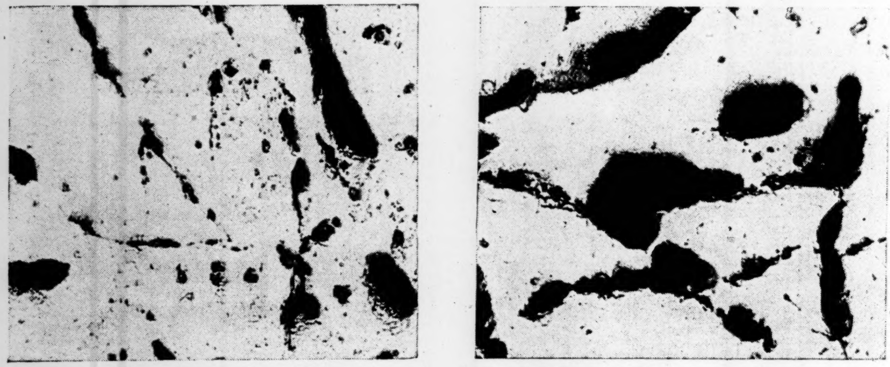
$$R = \frac{3\ Pl}{2\ bd^2}$$

where R = modulus of rupture, P = breaking load in pounds, l = length of span in inches, d = depth of specimen in inches and b = breadth of specimen in inches.



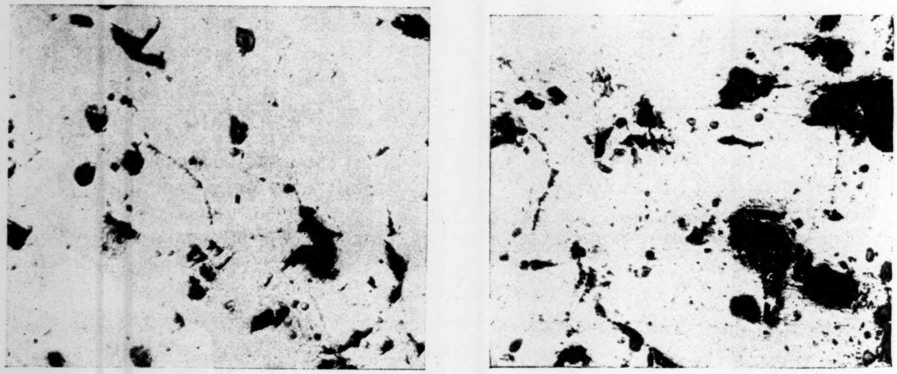
(*a*) 4-in. Wall Section—Skin.

(*b*) 4-in. Wall Section—Center.



(*c*) 2-in. Wall Section—Skin.

(*d*) 2-in. Wall Section—Center.



(*e*) 1-in. Wall Section.

(*f*) ½-in. Wall Section.

FIG. 3.—Photomicrographs of Unetched Specimen from Test Casting (× 100).

The arbitration test bars were likewise tested between 12-in. supports and elastic deflections were taken as above. The modulus of rupture was calculated from the formula:

$$R = \frac{Pl}{3.1416\, r^3}$$

where r = radius of bar in inches, and R, P, and l have the same meaning as in the first formula.

The results of the flexure tests are shown in Table I.

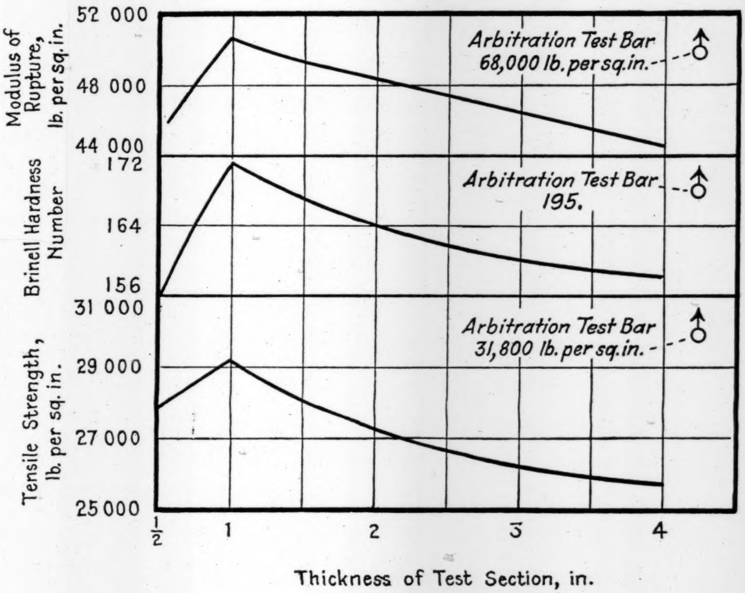


FIG. 4.—Variation of Average Physical Properties with Thickness of Test Section.

Tension Tests.—Tension test specimens were prepared from the bar specimens broken in the flexure test. Both skin and center specimens were prepared from the 4-in. and 2-in. specimens from the test casting.

The tensile strength tests were made in an Amsler machine. Self-aligning chucks made the stress purely tensile. Nevertheless, several of the specimens were broken through the fillets.

The results of the tensile strength and Brinell hardness tests are shown in Table II.

Photomicrographs.—Photomicrographs of typical sections of each wall were taken. Both skin and center specimens were photographed in the case of specimens taken from the 4-in. and 2-in. walls. Figure 3 shows these photomicrographs.

Brinell Hardness.—Brinell hardness tests were made on all tension test specimens and hardness determinations were also made across several wall sections. Since the latter check very closely with the hardness numbers obtained on the tension specimens they were not recorded.

Specific Gravity.—With a view to determining the reason for the low physical properties of the ½-in. section as compared with those of the 1-in. section, the specific gravities of 3 specimens of each of these sections were determined. The results of the specific gravity determinations were as follows:

	1-IN. SECTION	½-IN. SECTION
Specimen A	7.1372	7.0836
Specimen B	7.1235	7.0679
Specimen C	7.1301	7.0665

Discussion of Results.—Figure 4 shows the average hardness, modulus of elasticity, and tensile strength plotted against thickness of the various sections of the test casting. These properties have the characteristic rise in value with decrease of section until the 1-in. wall section is reached. At this point there is a sharp break in all three curves. The physical properties of the ½-in. section are lower than those of the 1-in. section. In trying to determine the reason for this, the photomicrographs were examined. Both sections had practically the same structure. Specific gravity determinations showed that the 1-in. section was appreciably the denser. The suggested explanation is that the ½-in. section, due to poor feeding, has a submicroscopic porosity which accounts for the low hardness and other properties.

REPORT OF COMMITTEE A-4
ON
HEAT TREATMENT OF IRON AND STEEL

During the past year the work of the committee has been transacted by correspondence and no meetings have been held.

The resignation of Mr. R. M. Bird from the committee has been accepted and Mr. A. W. Lorenz has replaced Mr. W. C. Hamilton as one of the representatives of the American Foundrymen's Association.

The committee recommends that the Tentative Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys) (A 119 – 28 T)[1] be slightly revised as indicated below, and that the definitions, as revised, be advanced to standard:

Quenching.—Change from its present form: namely,

> *Quenching.*—Immersing to cool.

to read as follows:

> *Quenching.*—Rapid cooling by immersion.

No change is recommended in the note to this definition.

Process Annealing.—Change to read as follows by the addition of the italicized word:

> Process Annealing.—Heating iron-base alloys to a temperature below or close to the lower limit of the critical *temperature* range followed by cooling as desired.

No change is recommended in the note to this definition.

Patenting.—Change to read as follows by the addition of the italicized words:

> Patenting.—Heating iron-base alloys above the critical temperature range followed by cooling to below that range in *air or in* molten lead *which is* maintained at a temperature of about 700° F. (365° C.).

No change is recommended in the note to this definition.

Tempering.—Change to read as follows by the addition of the italicized word:

> Tempering (also termed Drawing).—Reheating after hardening to some temperature below the critical temperature range followed by any *desired* rate of cooling.

No change is recommended in the note to this definition.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 759 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 117.

Graphitizing.—Change to read as follows by the addition of the italicized words and the omission of the word in brackets:

> **Graphitizing.**—Graphitizing is a type of annealing [of] ***for gray*** cast iron whereby some or all of the combined carbon is transformed to free or uncombined carbon.

Carburizing (Cementation).—Change the note to this definition to read as follows by the addition of the italicized words and the omission of those in brackets:

> NOTE.—The term "carbonizing" used in this sense is [undesirable and] ***incorrect so*** its use should be discouraged.

The above revisions in the tentative definitions were approved unanimously by the Joint Committee on Definitions of Terms Relating to Heat Treatment, consisting of three representatives of the American Society for Steel Treating, three representatives of the Society of Automotive Engineers and three representatives of the American Society for Testing Materials.

The above recommendation has been referred to letter ballot of Committee A-4 which consists of 45 members. The analysis of the vote of the committee is given in the following table:

Item	Affirmative	Negative	Not Voting
ADVANCEMENT OF TENTATIVE DEFINITIONS TO STANDARD			
Tentative Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys) (A 119 - 28 T), as revised	43	1	1

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 45 members; 43 members returned their ballots, of whom 37 have voted affirmatively, none negatively and 6 have refrained from voting.

Respectfully submitted on behalf of the committee,

H. M. BOYLSTON,
Chairman.

J. H. HALL,
Secretary.

EDITORIAL NOTE

The Tentative Definitions of Terms Relating to Heat Treatment Operations (Especially as Related to Ferrous Alloys), as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, page 426.

REPORT OF COMMITTEE A-5

ON

CORROSION OF IRON AND STEEL

Committee A-5 held two meetings during the past year. All of its work has shown substantial progress.

Subcommittee III on Inspection (J. H. Gibboney, chairman).—This subcommittee in its report appended hereto reports additional failures of the test sheets at Annapolis, all failures being in the non-copper bearing light gage sheets.

Subcommittee V on Total Immersion Tests (F. N. Speller, chairman).—In the report of this subcommittee appended hereto the completion of the Annapolis tests where the specimens were exposed for a period of 10 years totally immersed in running Severn River brackish water is reported. Special attention is directed to the conclusion that the results at Annapolis, as well as similar immersion tests at Pittsburgh and Washington, representing three widely varying kinds of water, namely, brackish, acid mine-drainage and filtered drinking water, show no material difference in corrosion resistance between the copper-bearing and non-copper bearing metals under the conditions of the tests. Progress is reported in the sea-water immersion tests at Key West, Fla., Portsmouth, N. H., and Port Arthur, Tex., and the extensive tests on rivets and plates on the hulls of three oil tankers. The subject of acid immersion tests has had careful investigation, and the subcommittee is now conducting a series of stationary tests in 20-per-cent sulfuric acid in a study of the factors involved in the test.

Subcommittee VI on Specifications for Metallic-Coated Products (F. F. Farnsworth, chairman).—This subcommittee has continued its study of wire and wire products. The following tentative specifications and methods of test with revisions as indicated in the report appended hereto are recommended for advancement to standard: Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 - 27 T), without revision.

Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire (A 111 - 27 T), as revised;

Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Tie Wires (A 112 - 27 T), as revised;

Tentative Specifications for Zinc-Coated (Galvanized) Wire Fencing (A 116 - 27 T), as revised;

Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving (A 117 - 27 T), as revised;

Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire (A 121 - 28 T), as revised; and,

Tentative Specifications for Zinc-Coated (Galvanized) Steel Wire Strand (A 122 - 28), as revised.

It is the feeling of the committee that the revised specifications represent the best thought on quality requirements for the various products and the specifications are recommended for adoption as standard.

The subcommittee is also recommending for immediate adoption revisions of the Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 - 24) as given in detail in the report appended hereto. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

The subcommittee is also recommending that the Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving (A 118 - 27 T) be revised and continued as tentative. The proposed revisions are given in the appended subcommittee report.

Sub-Committee VII on Methods of Testing (C. D. Hocker, chairman).—This subcommittee is continuing its research work on the study of accelerated testing methods for judging the resistance to outdoor corrosion of zinc coatings on iron and steel. The test consists essentially of submitting samples to alternate exposures of water spray and of a simulated industrial atmosphere produced by charging ordinary air with regulated amounts of sulfur dioxide and carbon dioxide. Four laboratories have constructed equipment for operating this test, and two others will probably build similar testing equipment. The interest in this work, as well as the confidence of the subcommittee members in this form of accelerated testing, appears to be increasing.

During the past year, the committee members have continued their studies to determine the conditions for consistent operation of the test. Supplementing observations on the effects of temperature and concentration of corroding gases, recent studies indicate the desirability of modifying the test by rotating, or otherwise moving, the samples inside the test box. Other conditions of test to be investigated include the frequency of wetting and drying cycles, methods of cleaning samples between cycles, and the effect of light.

When the conditions of operating this test are better worked out, its usefulness in judging resistance to corrosion will be checked by outdoor exposure tests. For this purpose samples are being held in reserve which are companion samples to those now being exposed by Subcommittee VIII on Field Tests of Metallic Coatings on its outdoor test racks.

At the March meeting in Detroit, Mich., Mr. E. S. Taylerson was elected chairman of the subcommittee for the ensuing term of two years.

Subcommittee VIII on Field Tests of Metallic Coatings (F. A. Hull, chairman).—In the report of this subcommittee appended hereto, inspection of the galvanized sheets, hardware, structural shapes, conduits, etc., on the test racks at Brunot Island, Pittsburgh, Pa., Altoona, Pa., State College, Pa., Sandy Hook, N. J., and Key West, Fla., is reported. At Brunot Island all of the 0.75-oz. and 1.25-oz. zinc-coated sheets, and 16 of the No. 18 sheets with 1.50-oz. coatings have failed, and at Altoona all of the 0.75-oz., 1.25-oz. and 1.50-oz. zinc-coated sheets have failed at the end of about 3½ years, the lighter coatings failing first. No failures have occurred at State College, Sandy Hook or Key West. These results indicate conclusively that a sulfur atmosphere of industrial centers produces soluble zinc compounds which greatly shortens the life of the coating. The hardware specimens at the end of about 16 months' exposure are showing failures in the cadmium, lead, calorized, and the sherardized and electroplated zinc coatings. The hot-dipped galvanized and hot-dipped aluminum coatings are giving very good results with no failures. Due to the large amount of laboratory work to be done to determine the weight and uniformity of coatings on companion specimens to those exposed on the rack, the full data on the tests will be delayed until next year.

A special group in the subcommittee has been organized to study the relative protection values of different chromium coatings of specified thickness upon typical base metals, with and without intervening coatings of copper and nickel. The larger part of the laboratory work will be done at the U. S. Bureau of Standards. The field tests on the racks at Brunot Island, State College, Sandy Hook and Key West will provide typical industrial, rural, sea coast and tropical atmospheric conditions of exposure.

Subcommittee IX on Metal Culvert Tests (H. E. Smith, chairman). —This subcommittee is making substiantial progress in its program of field tests and expects to install the first lot of culverts during the coming summer. The report of the subcommittee, appended hereto states that seven different types of base metal conforming to the commercial composition specifications for pure iron, copper-bearing pure iron, copper iron, copper-molybdenum iron, copper steel, low-copper bessemer steel and low-copper open-hearth steel will be used in the test. As far as practical all types will be exposed at each location, and about 100 culverts of each type will comprise the test under conditions of intermittent water flow. The manufacture of the culverts will be followed by a special group, and the installations will be made on typical highway and railroad projects under the usual present-day construction practices. This work is receiving the cordial support of highway departments, railroads and government agencies, and is attracting nation-wide interest.

A new subcommittee has been organized during the year under the chairmanship of V. F. Hammel to plan and carry out an investigation of the effect of cold working on the physical properties of structural steel before and after galvanizing by the hot-dipped process. This research was proposed to the Society by the Sectional Committee on Zinc Coating of Iron and Steel where the problem had assumed importance from reports of occasional embrittlement in important zinc-coated structural shapes. The project was approved by Committee E-9 on Correlation of Research as one that should be undertaken by the Society, and Committee A-5 was requested to form a suitable representative committee to direct the work.

The subcommittee appointed for this work comprises representatives of the National Electric Light Association and power utility companies, the principal users of this product, the structural steel manufacturers, the galvanizing and fabricating companies, and the zinc manufacturers, and is as follows:

V. F. Hammel (chairman), Electric Bond and Share Co.
B. J. Barmack, Commonwealth Edison Co.
L. W. Codding, Public Service Electric and Gas Co.
Thomas Gregory, Hanlon, Gregory Galvanizing Co.
H. O. Hill, McClintic-Marshall Co.
E. F. Kenney, Bethlehem Steel Co.
C. F. W. Rys, Carnegie Steel Co.
J. J. Shuman, Jones and Laughlin Steel Corp.
C. S. Trewin, New Jersey Zinc Co.

The subcommittee met in Pittsburgh, Pa., on May 15 and appointed sections to study all available reports of failures, program of tests and the necessary research facilities for conducting such an investigation. These sections will report at a meeting in June, and it is anticipated that actual work on the project will be under way in a short time.

Committee A-5 would again direct attention to the use of its data and statements for advertising purposes. Some instances of misuse have occurred. There is no intent to restrict or discourage the proper use of these data. The committee enlists the support of all interests in a careful observance of its resolution published in the 1929 report[1] respecting this important matter.

The committee records with deep sorrow the death of Allerton S. Cushman. Mr. Cushman was intimately identified with the early constructive work of the Society in the field of corrosion. He was largely responsible for the formation of its first committee on corrosion and served as chairman for a number of years. His early papers presented before the Society on the theory of corrosion created a profound interest and enthusiasm in seeking means for reducing the great economic losses due to corrosion. His memory will be a lasting inspiration to his friends.

The present officers of the committee have been reelected for the ensuing term of two years.

The following is the result of the letter ballot of the committee on the recommendations made in this report:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF EXISTING STANDARD			
Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 - 24), immediate adoption	38	0	11
II. PROPOSED REVISION OF TENTATIVE STANDARD			
Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving (A 118 - 27 T)	38	0	11
III. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A 110 - 27 T), without revision	38	1	9
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire (A 111 - 27 T), as revised	37	0	12
Tentative Specifications for Zinc-Coated (Galvanized) Iron or Steel Tie Wires (A 112 - 27 T), as revised	38	0	11
Tentative Specifications for Zinc-Coated (Galvanized) Wire Fencing (A 116 - 27 T), as revised	35	1	13
Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving (A 117 - 27 T), as revised	35	0	14
Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire (A 121 - 28 T), as revised	37	0	12
Tentative Specifications for Zinc-Coated (Galvanized) Steel Wire Strand (A 122 - 28 T), as revised	38	1	11

This report has been submitted to letter ballot of the committee, which consists of 111 members; 50 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

J. H. GIBBONEY,
Chairman.

JAMES ASTON,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 139 (1929).

EDITORIAL NOTE

The revisions of the Standard Methods of Determining Weight of Coating on Zinc-Coated Articles recommended for the first time and thus requiring a nine-tenths vote was approved by a unanimous vote at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, page **385**.

The proposed revision of the Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving was accepted for publication as tentative and the specifications as revised appear on p. 973.

The Tentative Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products, without revision; and Specifications for Zinc-Coated (Galvanized) Iron or Steel Telephone and Telegraph Line Wire; for Zinc-Coated (Galvanized) Iron or Steel Tie Wires; for Zinc-Coated (Galvanized) Wire Fencing; for Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving; for Zinc-Coated (Galvanized) Barb Wire and for Zinc-Coated (Galvanized) Steel Wire Strand, as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The specifications and methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 409, 294, 299, 302, 305, 308 and 311.

REPORT OF SUBCOMMITTEE III ON INSPECTION OF THE ANNAPOLIS TESTS

Subcommittee III on Inspection of the atmospheric tests on black metal sheets has held three meetings during the year: at Annapolis, Md., October 4, 1929; at Detroit, Mich., March 19, 1930; and at Annapolis, Md., April 24, 1930. The sheets at Annapolis were inspected at the two visits to this location.

On October 4, 1929, Messrs. Fleming, Gibboney, Passano, Smith, Taylerson and Thompson, representing the Bureau of Steam Engineering of the United States Navy Department, were present at the inspection; Messrs. McDonnell and Wheaton being absent. The following additional failures were recorded:

Sheet O-12 (No. 22 gage Low-Copper Open-hearth Steel, Series A) failed due to small hole in lower left corner of the sheet.

Sheet X-1 (No. 22 gage Low-Copper Pure Iron, Series B) manufactured by the Inland Steel Co. This sheet failed due to hole near the bottom of the sheet.

No detailed record regarding texture, color and adherence of rust, or photographs of failures were made at this inspection due to inclement weather conditions; however, all mechanical damage not previously noted was recorded by the inspectors.

The second inspection of the sheets at Annapolis was held on April 24, 1930, with Messrs. Gibboney, Humes (representing Mr. Passano), McDonnell, Taylerson and Thompson, representing the Bureau of Steam Engineering of the United States Navy Department, present; Messrs. Fleming, Smith and Wheaton being absent. Messrs. Schramm and Speller were visitors. The following additional failures were recorded:

Sheet X-5 (No. 22 gage Low-Copper Pure Iron, Series B) manufactured by the Inland Steel Co. This sheet failed due to small hole near the bottom of the sheet.

Sheet Z-417 (No. 22 gage Low-Copper Open-hearth Steel, Series B, copper 0.018 per cent), manufactured by the Youngstown Sheet and Tube Co. This sheet failed due to a fairly large hole about 18 in. from the bottom of the sheet.

No detailed record regarding texture, color and adherence of rust, or photographs of failures were made at this inspection; however, all mechanical damage not previously noted was recorded by the inspectors.

Table I (Plate I) is presented as a continuation of the same general plan of grouping the sheets at Annapolis as regarding the presence of copper and recording the failures at all inspection periods.

At the close of 13 years' observation at Annapolis, it is noted that all failures are in the non-copper-bearing metals.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

This report was considered by the subcommittee at its meeting at Annapolis on April 24, 1930, and was unanimously approved.

Respectfully submitted on behalf of the subcommittee,

J. H. GIBBONEY,
Chairman.

TABLE I.—FAILURES AT ANNAPOLIS TESTS. INSPECTIONS OF 1917, 1918, 1919, 1920, 1921, 1922,
COMPARING COPPER-BEARING WITH

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test		
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Mar. 5, 1923.[a] 77 Months	Oct. 10, 1923. 84 Months
												No. 16 GAG
EE	Puddled Iron	A	Copper-Bearing	0.035	0.03	0.119	0.018	0.125	0.319	12	None	None
HH	Copper-Bearing Basic Open-hearth Steel	A	" "	0.074	0.373	0.011	0.026	0.004	0.237	16	None	None
II	Copper-Bearing Bessemer Steel	A	" "	0.059	0.371	0.095	0.066	0.006	0.247	16	None	None
KK	Copper-Bearing Acid Open-hearth Steel	A	" "	0.108	0.433	0.085	0.043	0.005	0.234	18	None	None
CCC	Copper-Bearing Pure Iron	A	" "	0.023	0.026	0.005	0.028	0.005	0.236	12	None	None
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.080	0.313	0.009	0.020	0.006	0.223	14	None	None
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.018	0.066	0.008	0.028	0.005	0.239	14	None	None
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.046	0.007	0.019	0.004	0.299	14	None	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.113	0.413	0.109	0.045	.....	0.167	2	None	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.080	0.34	0.091	0.036	.....	0.293	3	None	None
ZZ	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.073	0.305	0.089	0.045	None	0.532	2	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.074	0.39	0.069	0.072	.....	0.255	3	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.077	0.363	0.057	0.080	0.002	0.652	2	None	None
ZZ	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.06	0.42	0.050	0.048	Trace	0.363	2	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	130	None	None
AA	Bessemer Steel	A	Non-Copper-Bearing	0.043	0.419	0.083	0.042	0.004	0.012	18	None	None
BB	Open-hearth Steel	A	" " "	0.056	0.349	0.022	0.048	0.037	0.113	17	None	None
CC	Copper-Bearing Pure Iron	A	" " "	0.019	0.029	0.004	0.032	0.003	0.067	12	None	None
DD	Low-Copper Pure Iron	A	" " "	0.019	0.028	0.004	0.027	0.004	0.028	19	None	None
OO	Low-Copper Open-hearth Steel	A	" " "	0.108	0.371	0.009	0.029	0.007	0.029	12	None	None
MM	Open-hearth Steel, Alan Wood Steel Co.	B	" " "	0.017	0.414	0.010	0.029	0.007	0.057	14	None	None
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.017	0.021	0.006	0.021	0.006	0.025	14	None	None
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.062	0.008	0.030	0.005	0.028	14	None	None
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.051	0.123	0.019	0.203	0.023	3	None	None
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.08	0.43	0.080	0.031	0.008	0.014	3	None	None
ZZ	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.047	0.389	0.040	0.027	0.007	0.033	3	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	129	None	None
												No. 22 GAGE
B	Open-hearth Steel	A	Copper-Bearing	0.06	0.27	0.014	0.053	0.006	0.187	9	None	None
C	Copper-Bearing Pure Iron	A	" "	0.015	0.028	0.006	0.036	0.003	0.194	9	None	None
E	Puddled Iron	A	" "	0.033	0.034	0.114	0.021	0.134	0.283	11	None	None
H	Copper-Bearing Basic Open-hearth Steel	A	" "	0.069	0.387	0.016	0.027	0.004	0.244	16	None	None
I	Copper-Bearing Bessemer Steel	A	" "	0.041	0.365	0.097	0.068	0.008	0.252	16	None	None
K	Copper-Bearing Acid Open-hearth Steel	A	" "	0.107	0.447	0.091	0.046	0.004	0.237	16	None	None
M	Open-hearth Steel, Alan Wood Steel Co.	B	" "	0.093	0.419	0.013	0.041	0.011	0.185	14	None	None
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.083	0.313	0.009	0.020	0.005	0.227	14	None	None
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.017	0.074	0.008	0.037	0.005	0.260	14	None	None
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.018	0.051	0.007	0.021	0.005	0.304	14	None	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.058	0.37	0.093	0.043	0.009	0.269	3	None	None
Z	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.055	0.38	0.110	0.046	.....	0.527	3	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.067	0.351	0.045	0.052	0.003	0.187	3	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.065	0.35	0.050	0.059	0.003	0.264	3	None	None
Z	Copper-Bearing Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.073	0.42	0.052	0.054	Trace	0.641	3	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	148	None	None
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.386	0.089	0.040	0.007	0.014	14	None	None
B	Open-hearth Steel	A	" " "	0.09	0.38	0.017	0.062	0.036	0.084	3	None	None
C	Copper-Bearing Pure Iron	A	" " "	0.01	0.028	0.002	0.027	0.002	0.141	3	None	None
D	Low-Copper Pure Iron	A	" " "	0.02	0.026	0.004	0.022	0.002	0.024	7	None	None
O	Low-Copper Open-hearth Steel	A	" " "	0.121	0.536	0.008	0.030	0.249	0.020	12	None	1 (1)
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.02	0.023	0.006	0.022	0.004	0.022	14	None	5 (1)
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.021	0.055	0.007	0.031	0.004	0.027	14	None	None
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	" " "	0.03	0.055	0.139	0.021	0.218	0.020	3	None	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.063	0.41	0.102	0.044	0.009	0.013	3	None	None
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.077	0.44	0.095	0.036	0.003	0.140	3	None	None
Z	Open-hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.032	0.32	0.063	0.042	.....	0.019	3	None	None
	Total	.....	.....	.....	.....	.....	.....	.....	.....	79	None	2

[1] In preparing this table, sheets below 0.15 per cent copper have been considered as non-copper-bearing, and those above 0.15 per cent copper as copper-bearing.

[a] No failures were recorded at inspections made prior to March 5, 1923; the detail records are accordingly not given here.

[b] Sheet B-4 shows mechanical damage to upper left-hand corner. Previously recorded as failure through error.

22, 1923, 1924, 1925, 1926, 1927, 1928, 1929, AND APRIL, 1930. SHEETS EXPOSED OCTOBER 17, 1916.
WITH NON-COPPER-BEARING MATERIALS.[1]

	Date of Inspection												Number of Sheets Failed in Test
23. ns	Apr. 18, 1924. 90 Months	Oct. 23, 1924. 96 Months	Mar. 27, 1925. 101 Months	Oct. 10, 1925. 108 Months	Mar. 29, 1926. 113 Months	Nov. 17, 1926. 121 Months	Mar. 21, 1927. 125 Months	Oct. 5, 1927. 132 Months	May 7, 1928. 139 Months	Apr. 25, 1929. 150 Months	Oct. 4, 1929. 156 Months	Apr. 24, 1930. 162 Months	
16 GAGE SHEETS													
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
22 GAGE SHEETS													
	None	None	None[b]	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	3, 4, 5, 9 (4)	2 (1)	6, 11 (2)	None	7, 10 (2)	None	None	12 (1)	None	11
	None	7 (1)	8 (1)	4 (1)	14 (1)	3 (1)	None	13 (1)	6, 11 (2)	1, 2, 9,10, 12 (5)	......	......	14 (all)
	None	None	None	None	None	None	4 (1)	None	None	None	1 (1)	5 (1)	3
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	1, 2, 3 (3)	....	......	......	3 (all)
	None	None	None	None	None	None	None	None	None	None	None	None	None
	None	None	None	None	None	None	None	None	None	None	None	417 (1)	1
	None	1	1	5	2	3	1	3	5	5	2	2	32

UNIV. OF MICH.

TABLE I.—REPORT ON TOTAL IMMERSION TESTS. SHEETS EX

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test	Aug. 6, 1925, 1890 Days	Sept. 9, 1925, 1924 Days	Oct. 22, 1925, 1967 Days	Nov. 24, 1925, 2000 Days	Feb. 19, 1926, 2087 Days	Mar. 25, 1926, 2121 Days
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper							
AA	Bessemer Steel	A	Non-Copper-Bearing	0.036	0.428	0.084	0.042		0.011	6		1, 10				
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.080	0.427	0.081	0.031	0.008	0.014	6	4	1			2	
II	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.062	0.353	0.093	0.065	0.006	0.255	6		1, 10				
ZZ1	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.112	0.412	0.109	0.045		0.167	6	103, 102, 102	102				
ZZ2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.076	0.340	0.088	0.034		0.291	6	202	201				
ZZ3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.072	0.305	0.089	0.045		0.532	6		307				
OO	Basic Open-Hearth Steel	A	Non-Copper-Bearing	0.109	0.358	0.011	0.029		0.025	6	1, 3, 4, 6	7, 8				
MM	Basic Open-Hearth Steel, Alan Wood Steel Co	B	" " "	0.110	0.420	0.008	0.027	0.010	0.063	6	2, 7, 15				5	
ZZ4	Basic Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.060	0.390	0.040	0.024		0.033	6	417, 418, 418, 418			417		
BB	Basic Open-Hearth Steel	A	" " "	0.046	0.296	0.025	0.058		0.138	6	3, 6, 9, 15					
HH	Copper-Bearing Basic Open-Hearth Steel	A	Copper-Bearing	0.083	0.369	0.011	0.026	0.002	0.252	6	2, 5, 12					
TT	Copper-Bearing Basic Open-Hearth Steel, Newport Rolling Mill Co	B	" "	0.087	0.338	0.008	0.019		0.221	6	1, 6, 8, 9					
ZZ5	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.078	0.390	0.071	0.075		0.256	6	503	501				503, 503
ZZ6	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.079	0.359	0.055	0.080		0.651	6						
ZZ7	Copper-Bearing Basic Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.060	0.420	0.050	0.048		0.363	6						
CC	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.022	0.031	0.005	0.031	0.003	0.086	6	7	3			5	
DD	Low-Copper Pure Iron	A	" " "	0.020	0.027	0.004	0.028	0.002	0.027	6	11, 15, 16	12, 13				
SS	Pure Iron, American Rolling Mill Co	B	" " "	0.022	0.032	0.005	0.018	0.007	0.027	6	3, 9, 17					6, 12
XX	Pure Iron, Inland Steel Co	B	" " "	0.028	0.079	0.009	0.029		0.034	6	3, 5, 7, 32, 35	2				
CCC	Copper-Bearing Pure Iron	A	Copper-Bearing	0.022	0.027	0.005	0.028	0.006	0.251	6	3, 4, 12, 15					
UU	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.028	0.071	0.006	0.031	0.006	0.247	6	4, 6, 7, 8		1			
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.024	0.051	0.006	0.017		0.308	6	1, 19, 30, 31, 32					
KK	Copper-Bearing Acid Open-Hearth Steel	A	Copper-Bearing	0.098	0.453	0.085	0.041		0.220	6	9, 12, 16	6				
YY	Low-Copper Puddled Iron, Youngstown Sheet and Tube Co	B	Non-Copper-Bearing	0.030	0.050	0.127	0.018	0.197	0.024	6	8, 8, 8, 8	9				9
EE	Copper-Bearing Puddled Iron	A	Copper-Bearing	0.045	0.026	0.114	0.019	0.117	0.300	6						
										150	60	17	1	1	3	5
	Total Failures to Date	....	....	....	....	....	....	....	....	....	60	77	78	79	82	87

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[a] Only one sheet, specimen EE8, had not failed.

s EXPOSED JUNE 2, 1920, IN RUNNING SEVERN RIVER WATER AT THE NAVAL ENGINEERING EXPERIMENT STATION, ANNAPOLIS, MD.

NO. 16 GAGE SHEETS

2121 Days	Apr. 24, 1926, 2151 Days	May 24, 1926, 2181 Days	June 24, 1926, 2212 Days	July 28, 1926, 2246 Days	Aug. 27, 1926, 2276 Days	Sept. 28, 1926, 2308 Days	Nov. 4, 1926, 2345 Days	Dec. 4, 1926, 2378 Days	Jan. 12, 1927, 2414 Days	Feb. 12, 1927, 2445 Days	May 6, 1927, 2528 Days	June 16, 1927, 2569 Days	July 19, 1927, 2602 Days	Sept. 29, 1927, 2674 Days	Dec. 5, 1927, 2741 Days	Jan. 7, 1928, 2774 Days	Feb. 11, 1928, 2809 Days	May 1, 1928, 2889 Days	June 19, 1928, 2938 Days	July 19, 1928, 2968 Days	Oct. 19, 1928, 3059 Days	Nov. 19, 1928, 3090 Days	Apr. 20, 1929, 3243 Days	May 20, 1929, 3273 Days	June 19, 1929, 3303 Days	July 19, 1929, 3333 Days
				2							1	4	13			4		7					16			
	202			103	103 306		9	204		307	201 306	15 306			307					18	201					24
	1													417		11										
, 503	16	12			3				501		1, 4 710, 711	602			710		710	605	610		711	602		602	711	
12	8 21			1			10				14															
	21		8	3		13																				
	3						7																			
9																										
	9												4		2			6								
5	8	1	1	4	3	1	3	1	1	1	8	4	2	1	3	2	1	3	1	1	2	1	1	1	1	1
87	95	96	97	101	104	105	108	109	110	111	119	123	125	126	129	131	132	135	136	137	139	140	141	142	143	144

TABLE I.—REPORT ON TOTAL IMMERSION TESTS. SHEETS EXPOSED JUNE 2, 1920, IN RUNNING SEVERN RIVER WATER AT THE NAVAL ENGINEE

NO. 16 GAGE SHEETS

	Average Analysis, per cent					Number of Sheets in Test	Aug. 6, 1925, 1890 Days	Sept. 9, 1925, 1924 Days	Oct. 22, 1925, 1967 Days	Nov. 24, 1925, 2000 Days	Feb. 19, 1926, 2087 Days	Mar. 25, 1926, 2121 Days	Apr. 24, 1926, 2151 Days	May 24, 1926, 2181 Days	June 24, 1926, 2212 Days	July 28, 1926, 2246 Days	Aug. 27, 1926, 2276 Days	Sept. 28, 1926, 2308 Days	Nov. 4, 1926, 2345 Days	Dec. 4, 1926, 2378 Days	Jan. 12, 1927, 2414 Days	Feb. 12, 1927, 2445 Days	May 6, 1927, 2528 Days	June 16, 1927, 2569 Days	July 19, 1927, 2602 Days
	Manganese	Phosphorus	Sulfur	Silicon	Copper																				
6	0.428	0.084	0.042		0.011	6		1, 10																	13
0	0.427	0.081	0.031	0.008	0.014	6	4	1			2					2							1	4	
2	0.353	0.093	0.065	0.006	0.255	6		1, 10											9					15	
2	0.412	0.109	0.045		0.167	6	103, 102, 102	102								103	103								
6	0.340	0.088	0.034		0.291	6	202	201					202							204			201		
2	0.305	0.089	0.045		0.532	6		307									306					307	306	306	
9	0.358	0.011	0.029		0.025	6	1, 3, 4, 6	7, 8																	
10	0.420	0.008	0.027	0.010	0.063	6	2, 7, 15				5														
30	0.390	0.040	0.024		0.033	6	417, 418, 418, 418			417															
16	0.296	0.025	0.058		0.138	6	3, 6, 9, 15						1												
33	0.369	0.011	0.026	0.002	0.252	6	2, 5, 12						16										1, 4		
37	0.338	0.008	0.019		0.221	6	1, 6, 8, 9							12			3								
78	0.390	0.071	0.075		0.256	6	503	501				503, 503									501				
79	0.359	0.055	0.080		0.651	6																		602	
60	0.420	0.050	0.048		0.363	6																	710, 711		
22	0.031	0.005	0.031	0.003	0.086	6	7	3			5		8			1			10						
20	0.027	0.004	0.028	0.002	0.027	6	11, 15, 16	12, 13					21												
22	0.032	0.005	0.018	0.007	0.027	6	3, 9, 17					6, 12											14		
28	0.079	0.009	0.029		0.034	6	3, 5, 7, 32, 35	2																	
22	0.027	0.005	0.028	0.006	0.251	6	3, 4, 12, 15								8			13							
28	0.071	0.006	0.031	0.006	0.247	6	4, 6, 7, 8		1							3									
24	0.051	0.006	0.017		0.308	6	1, 19, 30, 31, 32						21												
98	0.453	0.085	0.041		0.220	6	9, 12, 16	6					3						7						
30	0.050	0.127	0.018	0.197	0.024	6	8, 8, 8, 8	9				9													
45	0.026	0.114	0.019	0.117	0.300	6							9												4
						150	60	17	1	1	3	5	8	1	1	4	3	1	3	1	1	1	8	4	2
......	......	......	......	......	......	....	60	77	78	79	82	87	95	96	97	101	104	105	108	109	110	111	119	123	125

PLATE II.
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 30, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

GINEERING EXPERIMENT STATION, ANNAPOLIS, MD.

July 19, 1927, 2602 Days	Sept. 29, 1927, 2674 Days	Dec. 5, 1927, 2741 Days	Jan. 7, 1928, 2774 Days	Feb. 11, 1928, 2809 Days	May 1, 1928, 2889 Days	June 19, 1928, 2938 Days	July 19, 1928, 2968 Days	Oct. 19, 1928, 3059 Days	Nov. 19, 1928, 3090 Days	Apr. 20, 1929, 3243 Days	May 20, 1929, 3273 Days	June 19, 1929, 3303 Days	July 19, 1929, 3333 Days	Sept. 20, 1929, 3396 Days	Oct. 21, 1929, 3427 Days	Mar. 29, 1930, 3585 Days[a]	Group			
13			4		7					16							AA ZZ	2559.3 2240.7	2400.0	2358.2 Days
		307					18	201					24				II ZZ1 ZZ2 ZZ3	2510.5 2019.3 2321.7 2413.8	2316.3	
	417		11												9	12	OO MM ZZ4 BB	1901.3 2326.3 2039.0 2216.0	2120.6	2294.8 Days
		710		710	605	610		711	602		602	711		605		501	HH TT ZZ5 ZZ6 ZZ7	2146.2 2002.8 2342.5 3025.8 2828.0	2469.1	
																	CC DD SS XX	2107.0 1944.8 2073.3 1895.7	2005.2	1987.4 Days
																	CCC UU VV	2013.3 1962.2 1933.5	1969.6	
																	KK	2015.0	2015.0	2015.0 Days
																	YY	1934.2	1934.2	2363.9 Days
4		2			6											1	EE	2793.6	2793.6	
2	1	3	2	1	3	1	1	2	1	1	1	1	1	1	1	3				
125	126	129	131	132	135	136	137	139	140	141	142	143	144	145	146	149[a]				

UNIV. OF MICH.

TABLE II.—REPORT ON TOTAL IMMERSION TESTS. SHEET

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets In Test
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper	
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.380	0.090	0.036		0.017	6
Z	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.062	0.405	0.100	0.043		0.014	6
Z1	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.075	0.448	0.092	0.035		0.140	6
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.041	0.372	0.094	0.067	0.010	0.254	6
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.058	0.370	0.093	0.043		0.266	6
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.055	0.380	0.111	0.044		0.522	6
B	Open-Hearth Steel	A	Non-Copper-Bearing	0.023	0.229	0.012	0.052	0.004	0.117	3
F	Open-Hearth Steel	A	" " "	0.293	0.503	0.026	0.039	0.010	0.038	6
O	Low-Copper Open-Hearth Steel	A	" " "	0.118	0.522	0.009	0.029	0.223	0.021	6
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.042	0.318	0.063	0.042		0.019	6
B	Open-Hearth Steel	A	Copper-Bearing	0.038	0.232	0.009	0.063	0.004	0.167	3
G	Open-Hearth Steel	A	" "	0.290	0.510	0.027	0.039	0.010	0.241	6
H	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.076	0.371	0.011	0.028	0.002	0.246	6
M	Open-Hearth Steel, Alan Wood Steel Co.	B	" "	0.097	0.396	0.014	0.043	0.012	0.184	6
T	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.078	0.322	0.010	0.020		0.237	6
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.067	0.351	0.045	0.052		0.187	6
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.062	0.388	0.054	0.053		0.275	6
D	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.012	0.027	0.003	0.022	0.002	0.021	6
S	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.009	0.016	0.007	0.020	0.008	0.022	6
X	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.010	0.065	0.007	0.026		0.033	6
C	Copper-Bearing Pure Iron	A	Copper-Bearing	0.025	0.034	0.006	0.039	0.020	0.198	6
U	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.016	0.075	0.009	0.034	0.003	0.269	6
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.012	0.048	0.008	0.020		0.299	6
K	Copper-Bearing Acid Open-Hearth Steel	A	" "	0.112	0.438	0.090	0.044	0.002	0.231	6
E	Puddled Iron	A	Copper-Bearing	0.039	0.032	0.114	0.021	0.110	0.241	6
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.052	0.146	0.021	0.213	0.019	6
										150
	Total Failures to Date	....	....	....	....	....	....	....	....	....

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[a] All specimens in the inspection on this date were sand blasted to facilitate inspection.

Plate III.
Proceedings, Am. Soc. Testing Mats.
Vol. 30, Part I.
Report of Committee A-5:
Total Immersion Tests.

Sheets Exposed March 1, 1927, in Sea Water at U. S. Naval Station, Key West, Fla.

No. 22 Gage Sheets

	Number of Sheets in Test	Failures on Date of Inspections																					
		Mar. 16, 1928, 381 Days	Apr. 30, 1928, 427 Days	June 4, 1928, 462 Days	July 5, 1928, 493 Days	Sept. 7, 1928, 557 Days	Oct. 8, 1928, 588 Days	Nov. 7, 1928, 618 Days	Dec. 6, 1928, 647 Days	Jan. 7, 1929, 679 Days	Jan. 21, 1929,[a] 693 Days	Mar. 7, 1929, 738 Days	June 6, 1929, 829 Days	July 3, 1929, 856 Days	Aug. 7, 1929, 891 Days	Sept. 6, 1929, 921 Days	Oct. 7, 1929, 952 Days	Nov. 7, 1929, 983 Days	Dec. 6, 1929, 1012 Days	Jan. 7, 1930, 1044 Days	Feb. 10, 1930, 1078 Days
17	6		5					2						20				4			22
14	6			1			2			1	1				3				2		
40	6			102		101			101		101, 102, 108										
54	6			6, 21, 23						30					31						
66	6										204		202, 202, 204		206						
22	6										301				301				303		
17	3										15										
38	6			10						10					12						
21	6	15, 17		16							9, 28										
19	6	418		417, 418, 421											420						
67	3																17				
41	6				10																
46	6			11							8							2			
84	6					9									16		11				
37	6			2																	
87	6										501				501, 503, 504			503		504	
75	6			604											605, 606, 606, 607		606				
21	6											13				25					
22	6														2						4
33	6	3						1												18	
98	6										12										6
69	6																				
99	6							6													
31	6	3	6								27						8	15			
41	6							4							2	12	8				10
19	6	5		3		1			4		2				6						
	150	6	2	14	1	3	1	4	2	3	14	1	3	1	17	2	5	4	2	2	4
....	....	6	8	22	23	26	27	31	33	36	50	51	54	55	72	74	79	83	85	87	91

UNIV. OF MICH.

TABLE III.—REPORT ON TOTAL IMMERSION TESTS. SHE

Group	Designation	Series	Description	Average Analysi		
				Carbon	Manganese	Phosphorus
A	Bessemer Steel	A	Non-Copper-Bearing	0.038	0.380	0.094
Z	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0 061	0.400	0.114
Z1	Bessemer Steel, Youngstown Sheet and Tube Co	B	" " "	0.071	0.393	0.089
I	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.041	0.382	0 098
Z2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.050	0.380	0 089
Z3	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co	B	" "	0.041	0.365	0.095
B	Open-Hearth Steel	A	Non-Copper-Bearing	0.110	0.380	0.016
F	Open-Hearth Steel	A	" " "	0.293	0.503	0.026
O	Low-Copper Open-Hearth Steel	A	" " "	0.142	0.545	0 007
Z4	Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" " "	0.100	0.319	0.069
B	Open-Hearth Steel	A	Copper-Bearing	0.090	0.210	0.009
G	Open-Hearth Steel	A	" "	0.290	0.510	0.027
H	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.063	0.403	0.017
M	Open-Hearth Steel, Alan Wood Steel Co	B	" "	0.090	0.400	0.011
T	Copper-Bearing Steel, Newport Rolling Mill Co	B	" "	0.082	0.309	0 009
Z5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.060	0.360	0.047
Z6	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co	B	" "	0.075	0.390	0.053
D	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.033	0.025	0.004
S	Low-Copper Pure Iron, American Rolling Mill Co	B	" " "	0.016	0.020	0.006
X	Low-Copper Pure Iron, Inland Steel Co	B	" " "	0.016	0.054	0.006
C	Copper-Bearing Pure Iron	A	Copper-Bearing	0.032	0.025	0.005
U	Copper-Bearing Pure Iron, Allegheny Steel Co	B	" "	0.012	0.066	0.008
V	Copper-Bearing Pure Iron, Whitaker-Glessner Co	B	" "	0.017	0.048	0.006
K	Copper-Bearing Acid Open-Hearth Steel	A	" "	0.102	0.455	0.087
E	Puddled Iron	A	Copper-Bearing	0.024	0.034	0.111
Y	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co	B	Non-Copper-Bearing	0.030	0.058	0.154
	Total Failures to Date	...	...	...	...	...

[a] All specimens in the inspection on this date were sand blasted to facilitate inspection.

PLATE IV.
PROCEEDINGS, AM. SOC. TESTING MATS.
VOL. 30, PART I.
REPORT OF COMMITTEE A-5:
TOTAL IMMERSION TESTS.

SHEETS EXPOSED MARCH 7, 1927, IN SEA WATER AT U. S. NAVY YARD, PORTSMOUTH, N. H.

NO. 22 GAGE SHEETS

Analysis, per cent				Number of Sheets in Test	Failures on Date of Inspections															
Phosphorus	Sulfur	Silicon	Copper		Apr. 9, 1928, 399 Days	May 8, 1928, 428 Days	June 13, 1928, 464 Days	Jan. 4, 1929, 669 Days	Mar. 4, 1929, 728 Days	Apr. 6, 1929, 761 Days	May 1, 1929, 786 Days	June 3, 1929,[a] 819 Days	July 9, 1929, 855 Days	Aug. 7, 1929, 884 Days	Sept. 5, 1929, 913 Days	Oct. 2, 1929, 940 Days	Nov. 4, 1929, 973 Days	Dec. 4, 1929,[a] 1003 Days	Jan. 6, 1930, 1036 Days	Feb. 5, 1930, 1066 Days
094	0.042	0.007	0.012	6														35		
114	0.048		0.012	6													4	6	5	11
089	0.045	0.009	0.135	6							108									
098	0.068		0.250	6													33			36
089	0.037	0.005	0 259	6											207		213			
095	0.045		0.518	6												306			308	
016	0.065	0 013	0.082	4								30					32, 38	36		
026	0.039	0 010	0.038	6				11			10, 11							10		
007	0.027	0.217	0.015	6	30			33,34		32, 36	35									
069	0.044		0.018	6								424, 421					422	423		
009	0.060	0.004	0.190	2											25		23			
027	0.039	0.010	0.241	6			10,11		12											10
017	0.027	0.005	0.245	6	32	38	26	35			29									
011	0.039		0.187	6			22	29,35	38		33				26					
009	0 022		0.214	6				39		27		36			25			41	28	
047	0.056		0.198	6							509					506		506		
053	0.053	Trace	0.261	6					608							609	608			608
004	0.020		0.025	6			33					42	40			37	31	41		
006	0.023		0.018	6				19			34				21	25	30			36
006	0.032		0.025	6						22							30		32	35
005	0.030	0.006	0.178	6				32				28		22			24			34
008	0.039		0.258	6						38		33					29, 31	35	40	
006	0.021		0.302	6						39							30	27, 37		42
087	0.045		0.238	6														33, 39		36
111	0.022	0.146	0.297	6										16	14		36	13, 22		
154	0.020	0.223	0.021	6								8					6	7, 8, 9		
				150	2	1	5	9	3	6	8	8	1	2	6	5	17	18	5	9
....	....	....	....	....	2	3	8	17	20	26	34	42	43	45	51	56	73	91	96	105

UNIV. OF MICH.

REPORT OF SUBCOMMITTEE V ON TOTAL IMMERSION TESTS

Annapolis Immersion Tests:

The No. 16 gage sheet specimens exposed for 10 years in running Severn River water at the Naval Engineering Experiment Station, Annapolis, Md., were inspected monthly up to April 1, 1930. All but one sheet (specimen EE 8) out of the 150 sheets installed have failed, so the subcommittee has decided to conclude this test.

Table I (Plate II) gives a detailed record of the failures with the average life in days of the different classes of material. *It is apparent that there is no material difference in corrosion resistance between the copper-bearing and non-copper-bearing metals under the conditions of this test. The same conclusion was reached on completion of similar water-immersion tests at Pittsburgh, Pa., and at Washington, D. C.* A systematic analysis of these and other tests conducted by Committee A-5 will be found in a paper by V. V. Kendall and E. S. Taylerson presented before the Society in 1929.[1]

Sea Water Immersion Tests:

At Key West Navy Yard, the No. 22 gage sheets exposed March 1, 1927, in sea water showed a total of 91 failures out of 150 sheets originally in the test up to March, 1930. A detailed record of the failures is given in Table II (Plate III). At Portsmouth, N. H., where the No. 22 gage sheets were exposed in sea water March 7, 1927, 105 failures out of 150 sheets in the test were recorded up to March, 1930, as shown in Table III (Plate IV).

The No. 16 gage sheets exposed at Key West, Fla., March 1, 1927, showed a total of 6 failures out of 138 sheets in the test up to March, 1930, as shown in Table IV. At Portsmouth, N. H., two failures of the No. 16 gage sheets have been recorded to date, the first DD-50, on December 4, 1929, and the second, HH-32, on Feburary 5, 1930. Inasmuch as so few failures have occurred, a table is not included at this time.

Riveted plates and copper-steel pipe immersed in sea water were inspected at Key West, Fla., September, 1929, and January, 1930, and at Portsmouth, N. H., and Port Arthur, Tex., in September, 1929. The riveted plates at Key West and Portsmouth were cleaned and

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[1] V. V. Kendall and E. S. Taylerson, "A Critical Study of the A.S.T.M. Corrosion Data on Uncoated Commercial Iron and Steel Sheets," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 204 (1929).

TABLE IV.—REPORTS ON TOTAL IMMERSION TESTS. SHEETS EXPOSED MARCH 1, 1927, IN SEA WATER AT U. S. NAVAL STATION, KEY WEST, FLA.

No. 16 GAGE SHEETS

Group	Designation	Series	Description	Average Analysis, per cent						Number of Sheets in Test	Failures on Date of Inspections		
				Carbon	Manganese	Phosphorus	Sulfur	Silicon	Copper		Sept. 6, 1929, 921 Days	Oct. 7, 1929,[a] 952 Days	Nov. 7, 1929, 983 Days
AA	Bessemer Steel	A	Non-Copper-Bearing	0.030	0.420	0.085	0.040	0.003	0.012	6			
ZZ	Bessemer Steel, Youngstown Sheet and Tube Co.	B	" " "	0.080	0.440	0.080	0.032		0.014	6		1	
II	Copper-Bearing Bessemer Steel	A	Copper-Bearing	0.060	0.360	0.091	0.066	0.005	0.254	6			
ZZ2	Copper-Bearing Bessemer Steel, Youngstown Sheet and Tube Co.	B	" "	0.078	0.340	0.091	0.036		0.287	6			
BB	Open-Hearth Steel	A	Non-Copper-Bearing	0.058	0.359	0.022	0.049	0.005	0.109	6			
FF	Open-Hearth Steel	A	" " "	0.280	0.500	0.027	0.038	0.010	0.034	6			
OO	Low-Copper Open-Hearth Steel	A	" " "	0.110	0.360	0.008	0.029	trace	0.026	6			3
MM	Open-Hearth Steel, Alan Wood Steel Co.	B	" " "	0.111	0.400	0.010	0.028	0.011	0.053	6			
ZZ4	Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" " "	0.047	0.389	0.040	0.027	0.007	0.033	6	418		
GG	Open-Hearth Steel	A	Copper-Bearing	0.290	0.510	0.028	0.039	0.010	0.217	6			
HH	Copper-Bearing Basic Open-Hearth Steel	A	" "	0.069	0.371	0.010	0.026	0.004	0.248	6			
TT	Copper-Bearing Steel, Newport Rolling Mill Co.	B	" "	0.087	0.330	0.009	0.019	0.008	0.239	6			
ZZ5	Copper-Bearing Open-Hearth Steel, Youngstown Sheet and Tube Co.	B	" "	0.075	0.390	0.070	0.073		0.257	6			
CC	Low-Copper Pure Iron	A	Non-Copper-Bearing	0.020	0.027	0.005	0.033	0.003	0.078	6			
DD	Low-Copper Pure Iron	A	" " "	0.019	0.025	0.004	0.027	0.003	0.028	6			
SS	Low-Copper Pure Iron, American Rolling Mill Co.	B	" " "	0.015	0.021	0.006	0.020	0.005	0.023	6		6	
XX	Low-Copper Pure Iron, Inland Steel Co.	B	" " "	0.028	0.060	0.009	0.028	0.006	0.030	6		13	11
CCC	Copper-Bearing Pure Iron	A	Copper-Bearing	0.018	0.028	0.005	0.032	0.006	0.262	6			
UU	Copper-Bearing Pure Iron, Allegheny Steel Co.	B	" "	0.014	0.075	0.006	0.028	0.007	0.250	6			
VV	Copper-Bearing Pure Iron, Whitaker-Glessner Co.	B	" "	0.009	0.050	0.008	0.018		0.288	6			
KK	Copper-Bearing Acid Open-Hearth Steel	A	" "	0.100	0.460	0.085	0.039		0.230	6			
EE	Puddled Iron	A	Copper-Bearing	0.033	0.026	0.111	0.019	0.109	0.307	6			
YY	Low-Copper Wrought Iron, Youngstown Sheet and Tube Co.	B	Non-Copper-Bearing	0.030	0.050	0.124	0.019	0.210	0.021	6			
										138	1	3	2
	Total Failures to Date										1	4	6

[a] All specimens in the inspection on this date were sand blasted to facilitate inspection.

copper replicas made according to the method described in a paper by Mr. E. S. Taylerson presented before the Socity in 1929.[1]

A progress report was submitted by Mr. James French in regard to extensive tests of rivets and plates on oil tankers. These tests are being conducted on the hulls of the S. S. New York, the M. S. Chester Sun, and the M. S. Pacific Sun. No notable results have been obtained to date.

A special committee consisting of Messrs. F. B. Olcott and E. S. Taylerson has been appointed to review and redraft the instructions on both riveted plates and sheet samples at Portsmouth and Key West with a view to clarification of instructions. Photographs and copper replicas of the riveted plates will be made annually.

Acid Immersion Tests:

The special committee on Acid Immersion Tests reported that a very thorough study of the subject has been made and recommends that, while a more elaborate program may be necessary at a later date, the method of procedure which it submitted of conducting stationary immersion tests in 20-per-cent sulfuric acid could be carried out immediately to advantage. This action was approved by the subcommittee.

Arrangements have been made to run check tests and make other investigations of the factors in acid testing at the Laboratory of Applied Chemistry, Massachusetts Institute of Technology.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

This report was considered by the subcommittee at its meetings in Detroit, Mich., on March 20, 1930, and Annapolis on April 24, 1930, and was unanimously approved.

Respectfully submitted on behalf of the subcommittee,

F. N. Speller,
Chairman.

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[1] E. S. Taylerson, "Method of Making Copper Replicas of Corroded Metal Objects," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 234 (1929).

REPORT OF SUBCOMMITTEE VI ON SPECIFICATIONS FOR METALLIC-COATED PRODUCTS

This report covers the work of Subcommittee VI for the past year as presented at the meeting in Detroit, Mich., on March 20, 1930. The subcommittee is recommending, as given in detail below, the immediate adoption of a revision of one standard method of test, the adoption of one tentative method and is presenting revisions in seven tentative specifications all but one of which are being recommended for advancement to standard.

The subcommittee has, at this time, some work in progress with a view to developing of new specifications for metal-coated ferrous materials. The proposed specifications for sherardized coatings were not undertaken because of lack of active interest along this line. A section consisting of Messrs. W. H. Finkeldey, C. S. Trewin, and E. S. Taylerson (chairman) was appointed at the March meeting to investigate the desirability of preparing specifications for sprayed zinc coatings, and to report to the committee at the annual meeting in June.

PROPOSED REVISION OF STANDARD

Standard Methods of Determining Weight of Coating on Zinc-Coated Articles (A 90 - 24).[1]—The subcommittee recommends that the following revision of these methods be adopted immediately and the methods continued as standard. The committee accordingly asks for the necessary nine-tenths vote at the annual meeting for immediate adoption:

Section (b) Wire, Under Sampling.—Omit this section, including Table I, and substitute the following section:

(*b*) *Wire.*

For determining the weight of coating on zinc-coated wire, the use of a sample of a specific length is not necessary, since the density of the steel (0.283 lb. per cu. in) is known, it is only required to determine the diameter of the stripped wire and the ratio of the weight of zinc to the weight of the stripped wire. The sample of galvanized wire may be of any length over 12 in. but preferably about 24 in.

Section (b) Wire, Under Hydrochloric Acid - Antimony Chloride Method.—Omit this section, and substitute the following:

SOLUTIONS REQUIRED

Antimony Chloride Solution.—Dissolve 20 g. of antimony trioxide or 32 g. of $SbCl_3$ in 1000 cc. of HCl (sp. gr. 1.19).

Hydrochloric Acid.—Concentrated HCl (sp. gr. 1.19).

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 343.

PROCEDURE

The sample shall be cleaned with gasoline or benzine and dried thoroughly and then carefully weighed to 0.01 g.

The sample shall then be stripped of the zinc coating by immersing in a solution made by adding 1 cc. of the antimony chloride solution to 100 cc. of the concentrated HCl.

As soon as the violent chemical action on the wire ceases, the wire shall be removed from the acid, washed thoroughly and wiped dry.

The diameter of the wire shall than be determined to 0.001 in. by taking the mean of two measurements at right angles to each other. The stripped sample shall then be weighed to 0.01 g.

Calculation.—The original weight minus the weight of the stripped sample, divided by the weight of the stripped sample, gives the ratio of zinc to iron for the sample under test. The weight of coating in ounces per square foot of stripped wire surface is determined by multiplying the constant 163 by the diameter in inches of the stripped wire by the above ratio. This calculation may be expressed by the following formula:

$$\text{Ounces of zinc per square foot of stripped wire surface} = 163\,dr$$

where d = the diameter in inches of stripped wire;

$$r = \frac{\text{original weight} - \text{stripped weight}}{\text{stripped weight}}$$

REVISION OF TENTATIVE STANDARD

Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized Before Weaving (A 118 – 27 T).[1]—The subcommittee recommends that these tentative specifications be revised as follows and continued as tentative until such time as the manufacturers of this particular product have had full opportunity to comment on the revised tentative specifications.

Table I.—Change to read as follows by the omission of the words and figures in brackets:

TABLE I.—[COMMERCIALLY AVAILABLE] ZINC-COATED CHAIN-LINK FENCE FABRIC GALVANIZED BEFORE WEAVING.

NOMINAL DIAMETER OF WIRE, IN.	SIZE, STEEL WIRE GAGE	CLASS DESIGNATION	
		[WT. 7 DIP 4]	WT. 5 DIP 3
0.192	6	[✓]	✓
0.148	9	[✓]	✓
0.120	11	..	✓

No change is recommended in the note to this table.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 693 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 94.

ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD

The subcommittee recommends that the following seven tentative standards be advanced to standard with the following changes in six specifications:

Tentative Methods of Testing Zinc-Coated (*Galvanized*) *Iron and Steel Wire and Wire Products* (*A 110 – 27 T*)[1], without revision.

Tentative Specifications for Zinc-Coated (*Galvanized*) *Iron or Steel Telephone and Telegraph Line Wire* (*A 111 – 27 T*):[2]

Table I.—Change the title of this table to read as follows by the omission of the words in brackets:

Table I.—[Commercially Available] Zinc-Coated Iron or Steel Telephone and Telegraph Wire.

Tentative Specifications for Zinc-Coated (*Galvanized*) *Iron or Steel Tie Wires* (*A 112 – 27 T*):[2]

Table I.—Change the title of this table to read as follows by the omission of the words in brackets:

Table I.—[Commercially Available] Zinc-Coated Iron or Steel Tie Wires.

Tentative Specifications for Zinc-Coated (*Galvanized*) *Wire Fencing* (*A 116 – 27 T*):[2]

Title.—Change the title of these specifications to read as follows by the addition of the italicized words:

Tentative Specifications for Zinc-Coated (Galvanized) *Farm-Field and Railroad Right-of-Way* Wire Fencing.

Section 1.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

1. These specifications cover zinc-coated [woven-] wire fencing, [commercially known as farm or field fencing] *of the following commercial types: farm-field fencing and railroad right-of-way fencing.*

Section 4.—Change the second sentence from its present form: namely,

If copper is desired, the copper content shall not be less than 0.2 per cent.

to read as follows:

If copper is desired, the copper content shall conform to the following requirements:

Copper, minimum, per cent	Ladle analysis	0.20
	Check analysis	0.18

Table I.—Replace the present table with the following two tables. The revisions recommended in the table include the omission of all sizes

smaller than 12½ steel wire gage; sizes 6 to 9 inclusive have been given a class designation weight 5, dip 3 and sizes 10 to 12½ inclusive, weight 3½, dip 2. The class designation, weight 7, dip 4, for sizes 6 to 9 inclusive, have been omitted, as have weight 5, dip 3, for sizes 10 to 12 inclusive and weight 2, dip 1, for sizes 11 to 12½ inclusive:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 696 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 115.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 679–689 (1927); also 1929 Book of A.S.T.M. Tentative Standards, pp. 80–90.

TABLE I.—ZINC-COATED FARM-FIELD FENCE WIRE.

NOMINAL DIAMETER OF WIRE, IN.	SIZE, STEEL WIRE GAGE	CLASS DESIGNATION WT. 5 DIP 3	CLASS DESIGNATION WT. 3½ DIP 2
0.192	6	✓	..
0.177	7	✓	..
0.162	8	✓	..
0.148	9	✓	..
0.135	10	..	✓
0.120	11	..	✓
0.105	12	..	✓
0.098	12½	..	✓

TABLE II.—ZINC-COATED RAILROAD RIGHT-OF-WAY FENCE WIRE.

NOMINAL DIAMETER OF WIRE, IN.	SIZE, STEEL WIRE GAGE	CLASS DESIGNATION WT. 6 DIP 4
0.192	6	✓
0.177	7	✓
0.162	8	✓
0.148	9	✓

NOTE.—Sizes in which any given weight of coating may be regularly obtained in the open market are indicated by ✓ opposite the gage in the above tables.

In special cases wire may be obtained carrying weights 6 and 5 on smaller gages than indicated in the above table.

Section 8.—Change the last sentence to read as follows by the omission of the words in brackets:

Each roll shall carry a tag showing the class of coating [nominal weight of coating corresponding to Table I], the gage of the wire, the length of fencing in the roll, type of fencing, and the manufacturer's name or mark.

Tentative Specifications for Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving (A 117 - 27 T):[1]

Table I.—Change the title of this table to read as follows by the omission of the words in brackets:

Table I.—[Commercially Available] Zinc-Coated Chain-Link Fence Fabric Galvanized After Weaving.

Section 8.—Change the last sentence to read as follows by the omission of the words in brackets:

Each roll shall carry a tag showing the class of coating, [the nominal weight of coating], the gage of the wire, the length of fencing in the roll, and the manufacturer's name or mark.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 690 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 91.

Tentative Specifications for Zinc-Coated (Galvanized) Barb Wire (A 121 - 28 T):[1]

Table I.—Change to read as follows by the omission of the words and figures in brackets:

TABLE I.—[COMMERCIALLY AVAILABLE] ZINC-COATED BARB WIRE.

SIZE, STEEL WIRE GAGE	NOMINAL DIAMETER OF STRAND WIRE, IN.	CLASS DESIGNATION		
		[WT. 5 DIP 3]	WT. 3½ DIP 2	[WT. 2 DIP 1]
12	0.105	[✓]	✓	..
12½	0.098	[✓]	✓	..
14	0.080	[✓]	✓	[✓]

In the note to this table change the present third paragraph to read as follows by the addition of the italicized words and figures and the omission of the word in brackets and interchange the second and third paragraphs:

> For special purposes, barb wire galvanized before weaving may be obtained in *12½ and* larger [sizes] *gages*, carrying heavier coatings than indicated in the above table.

Tentative Specifications for Zinc-Coated (Galvanized) Steel Wire Strand (A 122 - 28 T):[1]

Section 4.—Add to this section a new first sentence, reading as follows:

> The zinc coating shall be tested for quantity by a stripping test only and for uniformity by the Preece test.

Table I.—Change the title of this table to read as follows by the omission of the words in brackets:

> Table I.—[Commercially Available] Zinc-Coated Steel Wire Strand.

In the table change the weight and dip designations of 0.104-in. wire from "weight 7, dip 3" to "weight 8, dip 4."

Table II.—In the heading of the first column add the words "nominal or" making this heading read "Nominal or Approximate Diameter of Strand, in."

Change the heading of the third column by the addition of the word "nominal," making the heading of this column read "Nominal Diameter of Wires in Strand, in."

Change the heading of the fourth column by the addition of the word "approximate" making the heading of this column read "Approximate Weight of Strand per 1000 ft., lb."

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, pp. 741, 744 (1928); also 1929 Book of A.S.T.M. Tentative Standards, pp. 97, 100.

In the body of the table the following changes are recommended in the requirements for $\frac{3}{8}$-in. strand: Change the nominal diameter of wires in strand from "0.125 in." to read "0.120 in."; and change the approximate weight of strand per 1000 ft. from "296 lb." to read "273 lb."

New Section.—Add a new section 6 reading as follows and renumber the present sections accordingly:

6. *Lay of Strand.*—All strand shall have a length of lay not to exceed sixteen times the nominal or approximate diameter of the strand in inches.

Section 8.—Change this section from its present form: namely,

8. (*a*) The size of the finished strand shall be expressed as the diameter of the wire in fractions of an inch.

(*b*) The permissible variations from the diameter of the strand shall be:

For strand, $\frac{5}{8}$ in. and over in diameter	±0.030 in.
For strand, $\frac{1}{4}$ to $\frac{9}{16}$ in., inclusive, in diameter	±0.020 in.
For strand, $\frac{1}{8}$ to $\frac{7}{32}$ in., inclusive, in diameter	±0.010 in.

to read as follows, renumbered as Section 9:

9. (*a*) The size of the finished strand shall be expressed as the approximate diameter of the strand in fractions of an inch.

(*b*) The diameter of the wire forming the strand shall be within the limits shown in the following table:

NOMINAL OR APPROXIMATE DIAMETER OF STRAND, IN.	NUMBER OF WIRES IN STRAND	DIAMETER OF WIRE, IN.		
		NOMINAL	MAXIMUM	MINIMUM
$\frac{1}{8}$	7	0.041	0.043	0.039
$\frac{5}{32}$	7	0.052	0.054	0.049
$\frac{3}{16}$	7	0.062	0.065	0.059
$\frac{7}{32}$	7	0.072	0.075	0.069
$\frac{1}{4}$	7	0.080	0.083	0.077
$\frac{9}{32}$	7	0.093	0.097	0.089
$\frac{5}{16}$	7	0.104	0.108	0.100
$\frac{3}{8}$	7	0.120	0.125	0.115
$\frac{7}{16}$	7	0.145	0.151	0.139
$\frac{1}{2}$	7	0.165	0.171	0.159
$\frac{1}{2}$	19	0.100	0.104	0.096
$\frac{9}{16}$	7	0.188	0.194	0.182
$\frac{9}{16}$	19	0.113	0.118	0.108
$\frac{5}{8}$	7	0.207	0.213	0.201
$\frac{5}{8}$	19	0.125	0.130	0.120
$\frac{3}{4}$	19	0.150	0.156	0.144
$\frac{7}{8}$	19	0.177	0.183	0.171
1	19	0.200	0.206	0.194
1	37	0.143	0.149	0.137
$1\frac{1}{8}$	37	0.161	0.167	0.155
$1\frac{1}{4}$	37	0.179	0.185	0.173

Section 12.—Change this section from its present form: namely,

> 12. For purpose of tests, a sample shall be taken from each reel or coil when the quantity of reels or coils does not exceed three. On larger quantities, samples for test shall be taken from 10 per cent of the lot.

to read as follows, renumbered as Section 13:

> 13. In quantities of three or less coils, a sample for all tests shall be taken from each reel or coil. On larger quantities, samples shall be taken from 10 per cent of the lot. If over 3 per cent of the samples fail in any one test, the entire lot may be rejected. In case there is a reasonable doubt as to the failure of the wire or strand in the first trial, two additional tests shall be made, and if no failure occurs in either of these tests, the wire or strand shall be considered acceptable.

The election of officers for the ensuing term of two years resulted in the selection of the present incumbent.

Respectfully submitted on behalf of the subcommittee,

F. F. FARNSWORTH,
Chairman.

REPORT OF SUBCOMMITTEE VIII ON FIELD TESTS OF METALLIC COATINGS

Subcommittee VIII has held two meetings during the year. Its activities and investigations of the several materials now being studied are described below.

GALVANIZED SHEET

A Special Committee on Inspection of Galvanized Sheet under the chairmanship of M. E. McDonnell has made several inspections during the year.

The rack at Altoona was inspected on April 23, 1929, by Messrs. Badger (representing G. A. Reinhardt), Hocker, Moody (representing M. E. McDonnell), Passano, Rawdon, Smith, Taylerson, Trewin and Willner; on July 23, 1929, by Messrs. Badger (representing G. A. Reinhardt), McDonnell, Passano, Reinhardt (representing C. S.Trewin), Speller (visitor) and Taylerson; on October 29, 1929, by Messrs. Anderson (representing C. S. Trewin), Hocker, Lundeen (representing R. F. Passano), McDonnell, Rawdon, Smith, Taylerson, Whitmer (visitor) and Willner; and on February 10, 1930, by Messrs. Lundeen (representing R. F. Passano), McDonnell and Taylerson.

The rack at Brunot Island was inspected on April 22, 1929, by Messrs. Badger (representing G. A. Reinhardt), Hocker, Moody (representing M. E. McDonnell), Passano, Rawdon, Schramm (visitor), Smith, Taylerson, Trewin and Willner; on July 22, 1929, by Messrs. Badger (representing G. A. Reinhardt), McDonnell, Passano, Reinhardt (representing C. S. Trewin), Smith and Taylerson; on October 28, 1929, by Messrs. Anderson (representing C. S. Trewin), Badger (representing G. A. Reinhardt), Hocker, Lundeen (representing R. F. Passano), McDonnell, Smith, Taylerson, Whitmer (visitor) and Willner; and on February 11, 1930, by Messrs. Lundeen (representing R. F. Passano), Moody (representing M. E. McDonnell) and Taylerson.

The rack at Sandy Hook was inspected on April 24, 1929, by Messrs. Duff, Giblin (visitor), Hocker, Moody (representing M. E. McDonnell), Pleister (visitor), Passano, Rawdon, Smith, Taylerson, Trewin and Willner; and on October 30, 1929, by Messrs. Farnsworth (visitor), Fisher (representing M. E. McDonnell), Giblin (visitor), Hocker, Lundeen (representing R. F. Passano), Pleister (visitor), Rawdon, Smith, Taylerson, Whitmer (visitor) and Willner.

The rack at Key West was inspected on January 20, 1930, by Messrs. Farnsworth (representing C. D. Hocker), Lundeen (representing R. F. Passano), McDonnell, Schueler (visitor) and Taylerson.

The rack at State College was inspected on April 23, 1929, by Messrs. Hocker, Knight (visitor), McDonnell, Passano, Rawdon, Smith, Sweeney (visitor), Taylerson, Trewin and Willner; and on October 29, 1929, by Messrs. Anderson (representing C. S. Trewin), Fisher (representing M. E. McDonnell), Hocker, Lundeen (representing R. F. Passano), Rawdon, Smith, Taylerson, Whitmer (visitor) and Willner.

Altoona and Brunot Island (Pittsburgh), Pa.:

As indicated in last year's report[1] the color gradings at Brunot Island and Altoona are very difficult due to the deposition of soot, dust and cinders on the sheets, while at Key West the color is obscured by a white adherent coating, apparently consisting of basic zinc carbonate. There is also a slight loose deposit of fine, white coral sand from the seashore. It is possible at all of the test racks to determine when the zinc coating has failed and when rough, red rust has developed, and it is also possible to determine fairly closely the percentage of the area rusted.

TABLE I.—RECORD OF COATING FAILURES ON ALTOONA TEST RACK. SHEETS EXPOSED APRIL 22, 1926.

Description	Number of Samples in Test	Apr. 7, 1927, 0.96 year	Sept. 28, 1927, 1.43 years	May 1, 1928, 2.03 years	July 27, 1928, 2.27 years	Oct. 30, 1928, 2.53 years	Jan. 28, 1929, 2.77 years	Apr. 23, 1929, 3.00 years	July 23, 1929, 3.25 years	Oct. 29, 1929, 3.52 years	Feb. 10, 1930, 3.81 years	Number of Samples Failed in Test	Average Life in Years
No. 16 Gage, 2.50 oz. per sq. ft...	10	None	None	None	None	None	None	None	None	None	None	None	...
No. 22 Gage, 2.50 oz. per sq. ft...	18	None	None	None	None	None	None	None	1	2	None	3	...
No. 22 Gage, 2.00 oz. per sq. ft...	18	None	None	None	None	None	None	None	6	4	None	10	(3.7)[a]
No. 22 Gage, 1.50 oz. per sq. ft...	18	None	None	None	2	4	None	1	11	..	..	18	3.0
No. 22 Gage, 1.25 oz. per sq. ft...	18	None	None	None	13	3	None	1	1	..	..	18	2.4
No. 22 Gage, 0.75 oz. per sq. ft...	14	None	6	1	7	..	..	..	..	..	..	14	1.9
No. 28 Gage, 0.75 oz. per sq. ft...	10	None	1	3	6	..	..	..	..	..	..	10	2.1
	106	None	7	4	28	7	None	2	19	6	None	73	
Total Failures to Date.......		None	7	11	39	46	46	48	67	73	73		

[a] Figures shown in parentheses are not to be considered as final.

Tables I and II show the record of the inspection of the sheets at Altoona and Brunot Island, respectively, which have rusted up to the present time, together with the time of exposure when this condition was first observed.

State College, Sandy Hook and Key West:

No base metal rust has yet occurred on any of the coated sheets at State College, Sandy Hook and Key West.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 146 (1929).

At State College the sheets still look bright and present substantially the same appearance as that reported a year ago.

At Sandy Hook more sheets show indication of yellowed areas than a year ago, but no coatings have failed at this point.

At Key West the zinc coating is apparently protected by the adherent white incrustation referred to in the foregoing, and no sheets yet show rust or even distinct yellowed areas. Preliminary laboratory tests made at Altoona indicate that the incrustation contains 16.94 per cent of CO_2, indicating basic carbonate of zinc. Chlorides were not found in this coating.

It has been definitely observed that the depreciation of the coating on the sheets at Brunot Island and Altoona is largely due to sulfur in the atmosphere, and white soluble salts have been accumulated and found by actual laboratory test to be largely water soluble and to be sulfur compounds of zinc.

TABLE II.—RECORD OF COATING FAILURES ON BRUNOT ISLAND TEST RACK. SHEETS EXPOSED APRIL 21, 1926.

Description	Number of Samples in Test	Apr. 6, 1927, 0.96 year	Sept. 27, 1927, 1.43 years	Apr. 30, 1928, 2.03 years	July 26, 1928, 2.27 years	Oct. 29, 1928, 2.53 years	Jan. 29, 1929, 2.78 years	Apr. 22, 1929, 3.00 years	July 22, 1929, 3.25 years	Oct. 28, 1929, 3.52 years	Feb. 11, 1930, 3.81 years	Number of Samples Failed in Test	Average Life in Years
No. 16 Gage, 2.50 oz. per sq. ft...	12	None	None	None	None	None	None	None	None	None	None	None	..
No. 22 Gage, 2.50 oz. per sq. ft...	18	None	None	None	None	None	None	None	None	None	None	None	..
No. 22 Gage, 2.00 oz. per sq. ft...	18	None	None	None	None	None	None	None	None	1	None	1	..
No. 22 Gage, 1.50 oz. per sq. ft...	18	None	None	None	None	None	None	None	10	3	3	16	(3.5)[a]
No. 22 Gage, 1.25 oz. per sq. ft...	18	None	None	None	None	2	None	None	16	..	..	18	3.2
No. 22 Gage, 0.75 oz. per sq. ft...	14	None	None	5	9	..	..	..	..	..	..	14	2.2
No. 28 Gage, 0.75 oz. per sq. ft...	10	None	None	2	8	..	..	..	..	..	..	10	2.2
	108	None	None	7	17	2	None	None	26	4	3	59	...
Total Failures to Date.......	.....	None	None	7	24	26	26	26	52	56	59		

[a] Figures shown in parentheses are not to be considered as final.

The results show conclusively that a sulfur atmosphere produces soluble zinc compounds and shortens the life of the coating. On the other hand, it is definitely shown that the adherent coating from tropical sea air which is formed on the sheets at Key West may have some protective value.

The tests also show conclusively that the tropical sea air at Key West and the sulfur-laden damp industrial atmosphere at Brunot Island both have a rapid corrosive action on uncoated black sheets which is more severe than that at Sandy Hook and Altoona, while at State College, where the atmosphere is relatively pure, the black sheets show much less corrosion.

In the following table are shown all No. 22 gage black sheet failures which have occurred in 3.75 years:

LOCATION	SHEET	LIFE IN YEARS
Altoona	YV-T	2.0
Brunot Island	RZ-T	2.0
	NB-T	3.0
	SN-B	3.3
	WL-B	3.0
	UX-T	2.5
	YH-B	2.0
	VC-B	2.3
Key West	RK-B	3.6
	NK-T	3.6
	SU-T	3.6
	WA-B	3.6
	VA-B	3.6
	TL-B	3.6
	YZ-T	2.6
	UV-B	3.6
Sandy Hook	YZ-B	3.5

From the above the committee would have it definitely understood that while coatings of galvanized sheets have failed in industrial atmospheres, none of the galvanized sheets have failed from a structural standpoint even in the No. 28 gage groups, and the results of further inspections must be obtained before final conclusions can be drawn.

Steps are being taken to analyze the black sheets, and it is expected that in the next annual report the committee will be able to give specific information relative to the influence of composition, including copper content, on the durability of the sheets on the Brunot Island and Key West test racks.

HARDWARE, STRUCTURAL SHAPES, CONDUITS, ETC.

A Special Committee on Inspection under the chairmanship of R. L. Duff, has made three inspections of the racks at Brunot Island, Altoona, State College and Sandy Hook, and one inspection of the Key West rack during the year. Diagrams showing the plan of installation and a description of the specimens on the test racks at the various locations are shown as Figs. 4 to 14 of last year's report.[1]

The hardware specimens, which as originally planned represented ordinary commercial jobs and nothing special, now exposed approximately 69 weeks, show very definite and complete corrosion in some types of coatings, while other types of coatings are in practically perfect condition. As would be expected, discrepancies are found at the different test locations in the failure of certain coatings, but in general, a fair degree of uniformity in breakdown of certain types of coatings and resistance to corrosion of other types were noted.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, pp. 151–158 (1929).

The coatings which seem to be consistently resistant to corrosion at all the locations are hot-dipped galvanizing and hot-dipped aluminum. Practically no rusting has occurred in either group of coatings, except on the re-tapped threads of the aluminum-coated ells and nipples. The excellent condition of the hot-dipped aluminum specimens is offset to a certain extent by their rough and non-uniform appearance. It would seem as though some improvements in the application of aluminum will have to be made before it can be considered a commercial product similar to hot-dipped galvanizing.

The sherardized and calorized specimens began to show the usual alloy rust or "blush" effect at the first inspection, which has progressed so that now nearly all of these samples are covered with yellow rust or small areas of red rust.

Parkerizing looked very promising after 4 months' exposure, but at the second inspection (10 months' exposure) very noticeable changes were noted. Samples which appeared to be in perfect condition at the first inspection showed serious breakdown 6 months later. It is interesting to note that where corrosion was found, it occurred in the form of heavy blisters. The behavior of the parkerized specimens seems to indicate that good protection is afforded so long as the oil film on the surface is present, but upon its gradual removal by the action of the elements, corrosion starts to take place vigorously.

The amaloy (lead coated) samples appeared to be more severely corroded at State College and Sandy Hook than at Pittsburgh or Altoona. Breakdown of amaloy coatings occurred in the nature of fine pits and pin holes.

Of the electroplated coatings, zinc has stood up better than cadmium. Several of the electro-zinc coatings are still in good condition, while others show considerable rust. The cadmium plated samples showed evidence of breakdown at the first inspection, and generally speaking seemed to be in the poorest condition of all the specimens on the racks. It is interesting to note that breakdown of the electroplated samples invariably started in the depressions or recessed parts of the specimens, indicating a non-uniformity of deposition of metal due to the "throwing power" of the solutions.

A definite statement, however, regarding the relative merits of these coatings cannot be made until the weights of coatings have been determined. Stripping tests on duplicate sets of all samples are now being made at different laboratories. This information, together with all tabulated data from the test racks will be available for the next report.

WIRE AND FENCING

The field test work on wire and fencing has been delayed due to the unsatisfactory condition of the samples collected, brought about from faulty conditions while holding the material in storage. A modified classification of the materials is now being developed and new material will be collected for the test. It is hoped that this work will be completed and the specimens placed on the test racks within the coming year.

CHROMIUM COATINGS

A special group has been organized in cooperation with the American Electroplaters' Society under the chairmanship of William Blum of the U. S. Bureau of Standards, with Messrs. F. A. Hull, W. M. Phillips, C. E. Mobius, R. J. O'Connor, A. K. Graham and Philip Sievering, to study the relative protective values of different chromium coatings of specified thickness, deposited under definite conditions, upon typical base metals, with or without intervening coatings of copper and nickel, and the relation between the results of laboratory or accelerated tests and typical atmospheric exposure. This work is a logical extension of the tests on chromium plating already under way. It is planned to expose about 500 specimens at the Brunot Island, State College, Sandy Hook and Key West locations, no space being available at the Altoona test racks for additional test material. This work is now under way and the specimens, which are being prepared at the Bureau of Standards, will be placed on the test racks during the coming year.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

This report was considered by the subcommittee at its meeting in Detroit, Mich., March 20, 1930, and was unanimously approved.

Respectfully submitted on behalf of the subcommittee,

F. A. HULL,
Chairman.

REPORT OF SUBCOMMITTEE IX ON METAL CULVERT TESTS

The Subcommittee on Metal Culvert Tests has continued very careful discussion of the desirable methods, materials and extent of a service test of corrugated sheet metal culverts. It has been agreed to begin such a test as soon as practicable. Base metals having the following chemical composition are to be used:

Pure Iron.—Sum of the elements carbon, manganese, phosphorus, sulfur, silicon, and copper, not more than 0.10 per cent.

Copper-Bearing Pure Iron.—Sum of the elements carbon, manganese, phosphorus, sulfur, and silicon, not more than 0.10 per cent; copper not less than 0.20 per cent.

Copper Iron.—Sum of the elements carbon, manganese, phosphorus, sulfur, and silicon, not more than 0.25 per cent; copper not less than 0.20 per cent.

Copper-Molybdenum Iron.—Sum of the elements carbon, manganese, phosphorus, sulfur, and silicon, not more than 0.25 per cent; copper not less than 0.40 per cent; and molybdenum not less than 0.05 per cent.

Copper-Bearing Steel.—Sum of the elements carbon, manganese, phosphorus, sulfur, and silicon, not more than 0.70 per cent; copper not less than 0.20 per cent.

Bessemer Steel.—Low copper, not over 0.05 per cent.

Open-hearth Steel.—Low copper, not over 0.05 per cent.

The culverts are to be of No. 14 gage sheet and will carry a 2-oz. zinc coating. In order to permit thorough inspection the majority of culverts will be 30 to 36 in. in diameter, but in no case less than 24 in. They will be installed under conditions of intermittent flow, avoiding markedly unusual features otherwise. It is expected that 100 culverts or more of each type will be used. These will be placed as rapidly as possible but the whole series will require two or three years. Thorough chemical analyses and tests will be made of the material.

The installations being considered at present are upon state highways and other public property, probably some on railroads and properties of other large consumers. Each individual culvert will be made entirely of one type of metal. The first installation will be made this summer. It is expected to secure other state highway locations in time to place additional culverts this year.

A group of five producer members of the subcommittee has been appointed to arrange for the manufacture and fabrication of the material. Close cooperation between production and installation is being arranged, so as to avoid delays.

The election of a chairman for the ensuing term of two years resulted in the selection of the present incumbent.

Respectfully submitted on behalf of the subcommittee,

H. E. SMITH,
Chairman.

REPORT OF SECTIONAL COMMITTEE
ON
ZINC COATING OF IRON AND STEEL

The Sectional Committee has held one meeting in Detroit, Mich., on March 20, 1930, during the year and submits the following report of its activities:

Technical Committee I on Hardware and Fastenings (A. L. Fox, chairman).—This committee reports that arrangements have been made for the selection of samples of hot-dipped galvanized products which would be representative of those in commercial use and expects to proceed with the tests to determine the weights and continuity of coatings. The results of a questionnaire relative to the various provisions which should be included in the specifications were submitted to the committee. An election of officers was held at which the present officers were re-elected.

Technical Committee II on Sheets and Sheet Products (G. A. Reinhardt, chairman).—This technical committee makes no further recommendation concerning the proposed Specifications for the Zinc Coating of Iron and Steel Sheets which were accepted by the Society two years ago for publication as information. No action was taken by the sectional committee on these specifications, which, therefore, are to be continued in their present status. No meeting of the committee has been held this year, but it is expected that the work will progress rapidly during the coming year.

Technical Committee III on Structural Steel Shapes, Plates and Bars and Their Products (V. F. Hammel, chairman).—This technical committee presented a report covering its activities from its inception up to and including its recommendation of specifications for submission to the American Standards Association for approval as American Tentative Standard. This committee is submitting revisions of the Specifications for Zinc Coatings of Plates, Bars, Structural Shapes and Their Products (A 123 - 29 T). These revisions were approved by the sectional committee and it is now recommended that they be accepted by the sponsor. It was the vote of the sectional committee that the sponsor should offer these revised specifications for formal approval by the American Standards Association. The revised specifications and the technical committee's report are appended hereto. Provision has been made in these specifications to cover the mooted question of embrittlement, and the Society is now actively organizing a comprehensive research to determine the properties of embrittlement and means to overcome embrittlement. After the findings of this research committee it is hoped to revise the section relating to embrittlement. An election of officers was held at which the present officers were re-elected.

Technical Committee IV on Pipes, Conduits and Their Fittings (F. N. Speller, chairman).—This committee reported that it had received no comments of any sort on its proposed specifications which had been published two years ago. Because of this, it is likely that the committee will suggest to the sponsor that the present A.S.T.M. specifications on this subject be adopted as standard.

Technical Committee V on Wire and Wire Products (C. E. Mobius, chairman).—This committee reported that a draft of Tentative Specifications for Zinc Coating (Galvanizing) on Iron and Steel Wire had been prepared and had received, by letter ballot, the unanimous approval of the appropriate subcommittee of the technical committee. Accordingly, these specifications were offered to the technical committee as a tentative standard. The Subcommittee on Stranded Wire intends to bring its work to conclusion as rapidly as possible. The Subcommittee on Woven-Wire Products and Fencing is working on specifications for these items which are being drafted along the lines of the present A.S.T.M. specifications. J. L. Shueler and C. S. Gordon have been elected chairman and vice-chairman, respectively, for the coming year.

Technical Committee VII on Methods of Testing (C. D. Hocker, chairman).—Technical Committee VII (functioning also as a subcommittee of the Society's Committee A-5 on Corrosion of Iron and Steel) is continuing its research work on the study of accelerated testing methods for judging the resistance to outdoor corrosion of zinc coatings on iron and steel. The test consists essentially of submitting samples to alternate exposures of water spray and of a simulated industrial atmosphere produced by charging ordinary air with regulated amounts of sulfur dioxide and carbon dioxide. Four laboratories have constructed equipment for operating this test, and two others will probably build similar testing equipment. The interest in this work, as well as the confidence of the committee members in this form of accelerated testing, appears to be increasing.

During the past year, the committee members have continued their studies to determine the conditions for consistent operation of the test. Supplementing observations on the effects of temperature and concentration of corroding gases, recent studies indicate the desirability of modifying the test by rotating, or otherwise moving, the samples inside the test box. Other conditions of test to be investigated include the frequency of wetting and drying cycles, methods of cleaning samples between cycles, and the effect of light.

When the conditions of operating this test are better worked out its usefulness in judging resistance to corrosion will be checked by outdoor tests. For this purpose samples are being held in reserve which are companion samples to those now being exposed on outdoor test racks by Subcommittee VIII, of the Society's Committee A-5 on Field Tests of Metallic Coatings.

At the meeting of the sectional committee in Detroit, the present officers were re-elected for the coming year. The committee decided that its work was of sufficient interest to warrant continuing its activities and in view of the fact that this matter is now cleared up, it is felt that the committee will be able to proceed in its work with renewed vigor.

The proposed specifications have been submitted to letter ballot of the sectional committee with the following results:

Item	Affirmative	Negative	Not Voting
ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Specifications for Zinc (Hot-Galvanized) Coatings on Structural Shapes, Plates and Bars and Their Products (A 123 - 29 T), as revised..............................	38	0	3

This report has been submitted to letter ballot of the sectional committee, which consists of 47 members; 41 members returned their ballots, 40 of whom have voted affirmatively and none negatively.

Respectfully submitted on behalf of the sectional committee,

J. A. CAPP,
Chairman.

A. B. CAMPBELL,
Secretary.

EDITORIAL NOTE

The Tentative Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, page 284.

In presenting the report at the annual meeting it was announced that Technical Committee II on Sheet and Sheet Products had voted to recommend to the sectional committee that the Standard Specifications for Zinc-Coated (Galvanized) Sheets (A 93 - 27) be submitted to the American Standards Association for approval as American Tentative Standard. It was proposed that if this recommendation of Technical Committee II should be approved at a meeting of the sectional committee the specifications would be referred to the Executive Committee of the Society for submission to the American Standards Association for approval. This method of procedure was approved, see Summary of Proceedings, p. 31.

REPORT OF TECHNICAL COMMITTEE III ON SPECIFICATIONS FOR ZINC COATING ON STRUCTURAL STEEL SHAPES, PLATES AND BARS AND THEIR PRODUCTS

The scope of this technical committee's activity, as originally defined in its title, was to develop specifications for zinc coating on structural steel shapes, plates and bars and their products.

Since its inception the technical committee has held eight meetings, and many subcommittee meetings.

Specifications:

The Specifications for Zinc (Hot-Galvanized) Coatings on Structural Steel Shapes, Plates and Bars and Their Products were submitted in preliminary form to the sectional committee at its meeting in Washington on March 23, 1928, and were approved at that meeting and subsequently accepted by the Society for publication as tentative.[1] Certain changes in the specifications as then published seemed desirable in view of constructive criticisms received from many different sources. The specifications were accordingly revised and again published by the Society as tentative.[2]

The specifications have been further reviewed and are now recommended for adoption as standard in their proposed revised form as appended hereto.[3] The principal points which have received consideration and revision are discussed briefly in the following paragraphs.

Steel Base Specifications.—Originally structural steel complying with the A.S.T.M. Specifications for Structural Steel for Bridges (A 7), Structural Steel for Buildings (A 9) and the Manufacturers' Standard Specifications for Class A and Class B Steels was defined as base material, for the protective coatings of which these specifications were to apply. After several revisions, this feature of the specifications is now covered by the following paragraph:

> These specifications presuppose the use of steel of recognized manufacture conforming to standard specifications.

Permissible Impurities in the Galvanizing Spelter Bath.—In addition to specifying that the grade of spelter to be used shall be equal to Prime Western, Technical Committee III considers it desirable to limit the amount of impurities contained in the molten zinc bath during the galvanizing operation, since it is sometimes the practice to make metallic additions to the galvanizing bath (other than slab zinc) on the basis that such additions are fluxes and assist in the galvanizing operation. In view of the fact that the impurity limits in Prime Western metal are set high, normal operation of the galvanizing bath, using grades of Prime Western spelter available to galvanizers, gives a zinc bath in the galvanizing pot having impurities lower than the limit set for Prime Western metal. The present form of the requirements in the specifications covering this point now reads:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 748 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 104.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 585 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 104.

[3] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part I, p. 284.

> The amount of lead or iron in the bath during actual galvanizing operations shall not exceed the limits allowed for "Prime Western" slab zinc (spelter), namely, lead 1.60 per cent and iron 0.08 per cent. The aluminum content shall not exceed 0.01 per cent.

The method for obtaining samples from the galvanizing bath for analysis has been provided for, which clause has received editorial revision to give greater clarity. A new clause has been added to the specifications which provides that the cost of analyzing samples taken from the zinc bath shall be borne by the purchaser.

Steel Embrittlement.—It was early recognized that the question of the embrittlement of the steel by the galvanizing process should receive some recognition in the specifications. The first drafts covered this point by stating that:

> *In so far as possible* the process of pickling and zinc coating shall not cause embrittlement of the base material nor change its physical or chemical characteristics.

An explanatory note was included which called attention to the fact that:

> In isolated cases steels are encountered which are susceptible to embrittlement by the normal hot-dip galvanizing processes. Such embrittlement may depend on the chemical composition of the steel or a process of cold working the material in fabrication. Proper heat treatment or other means to correct embrittlement should be covered by separate contract between the purchaser and the manufacturer.

This question of steel embrittlement has provided more discussion than any other single point in the specifications. The galvanizers, who in many cases have no direct connection with any steel producer, have been reluctant to accept the responsibility of embrittled steel since they claim the steel producers are equally reluctant to accept the responsibility for steel so embrittled. The steel producers have contended that such embrittlement is a result of the galvanizing operation and, therefore, the fault of the galvanizer. On the other hand, some consumers have received embrittled steel from galvanizers and are firm in their demand for protection against material of this sort. The clause in the latest revision of the specifications is in the nature of a compromise. This clause now reads:

5. (*a*) The finished material shall not be embrittled. (Note 3.)

(*b*) The purchaser shall bear the expense of making all embrittlement tests and the responsibility for delays in shipment incidental thereto.

NOTE 3.—Steels are encountered which are susceptible to embrittlement by the normal hot-dip galvanizing processes. Such embrittlement may depend on properties inherent in the steel, or on a method of cold working the material, or on the galvanizing processes. The present state of the art being such that embrittlement cannot be controlled and it being the belief that the causes and remedies can only be ascertained through cooperative research by the parties interested, these specifications do not unqualifiedly reject embrittled materials. Therefore, if, notwithstanding precautions taken by the manufacturers in the galvanizing and in the selection of the steel, embrittlement results, rejections are not to be enforced unless the liability is specifically provided for by contractual agreement between the purchaser and the manufacturer.

As a further step in clarifying this embrittlement situation, Technical Committee III has been instrumental in securing the support of the steel interests, the galvanizers and the consumers on a joint research program to determine the causes of steel embrittlement. Steps are now being taken by the Society's Committee A-5 on Corrosion of Iron and Steel to undertake an investigation to determine the properties of embrittlement.

Weight of Zinc Coating.—The weight of zinc coating per square foot of stripped surface was specified in the earlier drafts of the specifications to be 2 oz. on material $\frac{3}{16}$ in. thick and under, and $2\frac{1}{2}$ oz. on material over $\frac{3}{16}$ in. thick. It was first thought that the weight of coating could be determined by stripping coupon specimens of similar thickness attached to the material being galvanized. It was found after a long and thorough investigation that this method of determining the weight of zinc coating was not feasible. This same investigation and careful investigations made by a number of the galvanizers in their own shops indicate that the weight of zinc coating as specified above was too high. A revision was made in the specification and this point is now covered as follows:

6. The weight of the zinc coating per square foot of actual surface shall not average less than 2.0 oz., and no individual specimen shall show less than 1.8 oz.

7. (*a*) Test specimens shall be selected from the material being galvanized and shall be galvanized at the same time, in the same manner and in the same pot as the material whose coating characteristics they are intended to indicate. If the lot of material is of inconvenient lengths, pieces of the same shape but of convenient lengths for handling (at least three feet long) may be substituted as test specimens. (Note 4.)

(*b*) Three specimens may be required from each shift for carrying out the determination of the weight of coating as described in Section 8.

(*c*) No test specimen shall be used for the determination of the weight of coating which would fail to conform to other requirements of these specifications.

NOTE 4.—The use of convenient lengths of material for test specimens should not be interpreted to mean that small pieces of flat plate or odd shapes can be substituted for test specimens. Practice has shown that coupon specimens do not give true indications of the weight of coating on the shapes.

Provision is made in an additional clause to determine the weight of zinc coating by the stripping method in accordance with the Society's Standard Methods for Determining Weight of Coating on Zinc-Coated Articles.

Uniformity of Zinc Coating.—In view of the general condemnation of the Preece test by the Society,[1] Technical Committee III did not consider it advisable to include this test as a method of determining the weight or thickness of the zinc coatings or their uniformity. However, careful investigation over the last two or three years indicates that the consumers of galvanized structural steel materials are using this test in many cases to determine the uniformity of the zinc coating.

The question of uniformity was originally covered in the specifications on the basis of a visual examination by the purchaser's inspector. A revision of this clause appears in the present form of the specifications as follows:

11. The uniformity of the zinc coating shall be determined by visual inspection. If, in the opinion of the inspector, visual examination is not conclusive, he may use the Preece Test as described in the appendix to the Standard Methods for Determining Weight of Coating on Zinc-Coated Articles (A.S.T.M. Designation: A 90) of the American Society for Testing Materials. This test shall not be used to determine the weight of coating and shall only be applied after the coating has been found to conform to the requirements of Section 6 (weight of coating tests previously described).

The specifications in their proposed revised form have received the unanimous approval by letter ballot of Technical Committee III.

Special Investigations:

Use of Coupons to Determine the Weight of Zinc Coating.—As mentioned above, an investigation was made to determine the feasibility of attaching to the work being galvanized coupon test specimens on which weight of coating tests could be made. The coupons were in the form of flat plates having the same thickness as the section to which they were attached. These sections consisted of 3-ft. lengths of I-beams, channels, angles, and plates of various widths and dimensions. Three coupons were attached to each test section. The following companies each galvanized a set of these test specimens and coupons:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part I, p. 144 (1917).

American Bridge Co.,
Aermotor Co.,
Blaw-Knox Co.,
Bessemer Galvanizing Works,
Lehigh Structural Steel Co.,
Muskogee Iron Works, Inc.,
Riter-Conley Co.

The work of stripping the test sections and coupons to determine the weight of coating and an analysis of the test data was done at the research laboratories of the New Jersey Zinc Co. The following conclusions were drawn from this investigation:

1. The weight of coating found on the coupons showed no agreement with the weight of coating on the work to which they were attached. Furthermore, there was very poor agreement between the weights of coatings of the three individual coupons attached to each test specimen.

2. The weight of coating on the coupons in some cases was higher and in others lower than the coating weight of the test section. Differences as great as 2 to 3 oz. were not uncommon.

3. The weight of coating on structural materials was over 2 oz. per sq. ft. of surface coated.

Manufacturers' Investigation to Determine Amount of Zinc Coating on Galvanized Structural Steel.—To secure further information on the probable weight of zinc coating to be expected on galvanized structural materials, the following manufacturers made a series of weight-of-coating tests and other experiments on full-size sections:

American Bridge Co.,
Blaw-Knox Co.,
Riter-Conley Co.,
Walter Bates Steel Corp.

The most extensive of the experiments were made at the plant of the Riter-Conley Co. who had retained the Robert W. Hunt Laboratories to assist them in making their investigations. The results of these investigations showed that:

1. The weight of coating varied with the length of time the work was kept in the galvanizing bath, the longer the time the heavier the coating.

2. The weight of coating to be expected in ordinary commercial practice with an immersion in the zinc bath of 1½ minutes averaged about 2 oz. per sq. ft. of surface coated although certain individual tests in some of the companies' plants ran as low as 1.8 oz. per sq. ft.

3. The weight of coating on rusted material, that is, stocks stored in the yard and allowed to rust badly before galvanizing, was higher than the weight of coating on similar sections of new unrusted material.

Determination of Impurities in the Galvanizing Bath.—In view of the fact that the specifications limit the quantity of certain metallic impurities which may be contained in the molten zinc bath, it was thought desirable to find out what the normal amount of such impurities would be in the galvanizing bath during regular commercial operation. Samples were obtained during actual operation from the galvanizing pots of three large galvanizers of structural steel and analyzed for lead, iron, cadmium and aluminum. It was found that the lead content ranged from 0.96 to 1.1 per cent; the iron from 0.04 to 0.06 per cent; cadmium from 0.63 to 0.83 per cent and the aluminum reported as a trace (probably less than 0.009 per cent) in all cases.

Quenching of Galvanized Structural Steel.—It is common practice in many structural steel galvanizing plants to quench the work in water shortly after it is drawn from the zinc bath. A number of tests were made in several of the large structural steel galvanizing plants to determine what effect this quenching would have on the properties of the coating as well as the steel base material. The results of many tests made on quenched and air-cooled failed to show that quenching had any effect either good or bad on the properties of the zinc coating or on the properties of the steel base providing the air cooling was conducted properly. It was found that quenching eliminates one serious cause of coating peeling which frequently results when galvanized articles are nested or racked up in piles while still fairly hot in such a manner that air cooling is materially delayed.

In the opinion of the investigators any ill affects laid to quenching in the past were probably cases of hydrogen embrittlement of the steel.

Respectfully submitted on behalf of the technical committee,

V. F. HAMMEL,
Chairman.

W. H. FINKELDEY,
Secretary.

REPORT OF COMMITTEE A-6

ON

MAGNETIC PROPERTIES

One meeting of Committee A-6 on Magnetic Properties was held during the past year, in March, at Detroit, Mich., in connection with the Group Committee Meetings.

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Definitions and Nomenclature (W. J. Shackelton, chairman).—This subcommittee is recommending additional definitions and a revision of certain terms in the Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 - 29 T) as mentioned later in the report.

It was decided in view of the present activities of the sectional committee functioning under the American Standards Association and the U. S. National Committee of the International Electrotechnical Commission with which the committee is in close touch through two of its members, to postpone, for the present, the adoption of Tentative Definitions A 127 - 29 T, since it is quite probable that within the next year certain changes will need to be made to conform with the international action.

Subcommittee II on Alternating Current Tests at Low Inductions (R. L. Sanford, chairman).—A series of ring samples of ferro-magnetic materials having a wide variation in magnetic properties has been supplied by the Bell Telephone Laboratories and these specimens have been tested by several members of the committee and by a number of methods at 60 and 1000 cycles for permeabilities and losses at low inductions. The results obtained by various laboratories agree very well and it is believed that before long two or more methods of test may be selected to form the basis of tentative test procedures.

Subcommittee III on Tests at High Magnetizing Forces (L. E. Howard, chairman).—Work has been continued actively by various members of the subcommittee. The agreement between available methods is unsatisfactory and more fundamental work must be carried out before specifications for test procedures can be formulated.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Tentative Revision of Standard.—The committee last year recommended a revision in Section 5 (*c*) of the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 28).[1] After further consideration it is recommended that the last phrase of this new section reading "and shall be some multiple of [200] *300*," be omitted, and the revision continued as tentative.

Proposed Revision of Tentative Standard.—The committee recommends that the Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127 – 29 T)[2] be revised by the addition of new definitions for the terms magnetic circuit, magnetic potential difference, dia-magnetic, para-magnetic, ferromagnetic, and linkage, and revision of the term induction, the unit of reluctance, and the unit of magnetic force. The committee recommends that the definitions as revised and with the additions indicated below be continued as a tentative standard:

Magnetic Force.—At the suggestion of Mr. A. W. Smith the committee feels it would be advisable to adopt a new name for the unit of magnetic force other than the "gilbert per centimeter" and recommends the name "rowland" for this unit. It is accordingly recommended that the definition of the unit of this term be changed to read as follows by the addition of the italicized word and the omission of the words in brackets:

> Unit: [gilbert per centimeter] *Rowland.*—The magnetic force of one gilbert per centimeter.

Induction.—Change the definition of induction to read as follows by the addition of the italicized word and the omission of the word in brackets:

> Induction (Flux Density), *B.*—The flux per unit area normal to the direction of the [induction] *flux.*

Reluctance.—Under this term add the following definition for the unit oersted:

> Unit: *Oersted.*—The reluctance of a portion of an empty space one centimeter in length and having a cross-section of one square centimeter.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 162 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 812.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 589 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 121.

The following additional definitions are suggested:

Magnetic Circuit.—A closed path of magnetic flux.

Magnetic Potential Difference.—The magnetomotive force between two points.

Dia-magnetic.—A descriptive term applied to a material, the permeability of which is less than unity.

Para-magnetic.—A descriptive term applied to a material, the permeability of which is slightly greater than unity and is approximately independent of the magnetic induction.

Ferro-magnetic.—A descriptive term applied to a material, the permeability of which is considerably greater than unity.

Linkage.—The product of the flux in maxwells by the number of turns in a coil or winding linked therewith.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following result:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF TENTATIVE STANDARD			
Proposed Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing (A 127-29 T)	10	1	4
II. PROPOSED TENTATIVE REVISION OF STANDARD			
Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 - 28)	12	0	3

The present officers of the committee have been re-elected for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 15 members; 13 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

THOMAS SPOONER,
Chairman.

R. L. SANFORD,
Secretary.

EDITORIAL NOTE

The proposed revision of the Tentative Definitions of Terms, with Units and Symbols, Relating to Magnetic Testing, was accepted. The definitions in their revised form appear on page 983.

The proposed tentative revision of the Standard Methods of Test for Magnetic Properties of Iron and Steel was accepted for publication as tentative and appears on page 1271.

REPORT OF COMMITTEE A-7

ON

MALLEABLE CASTINGS

During the past two years Committee A-7 on Malleable Castings held two meetings: one at Chicago, Ill., on March 21, 1929, and the other at Detroit, Mich., on March 20, 1930. At the Chicago meeting the committee adopted resolutions in memory of the late F. L. Sivyer of the Northwest Malleable Iron Co., a member of the committee for a number of years, who had died during the year.

At the Chicago meeting in 1929 the committee discussed the advisability of revising the yield point requirement in the Standard Specifications for Malleable Castings (A 47 – 27).[1] At the Detroit meeting definite action was taken to recommend an increase in the yield point requirement to 32,500 lb. per sq. in. from the present value of 30,000 lb. per sq. in. This recommendation is offered for immediate adoption, and the committee asks for the necessary nine-tenths vote at the annual meeting.

The subject of yield point as related to malleable castings has been the subject of considerable discussion by the committee The method of determining yield point has likewise been discussed by the committee. The committee is also considering the advisability of writing additional specifications for malleable castings having lower tensile strength requirements than 50,000 lb. per sq. in., with suitable requirements for impact tests, machineability, and galvanizing properties. The committee, however, is not yet prepared to report on such specifications.

The above recommendation has been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
PROPOSED REVISION OF STANDARD			
Standard Specifications for Malleable Castings (A 47 – 27), immediate adoption........	23	1	3

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 438.

This report has been submitted to letter ballot of the committee which consists of 26 members; 24 members returned their ballots, of whom 23 have voted affirmatively and 1 negatively.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

Respectfully submitted on behalf of the committee,

W. P. PUTNAM,
Chairman.

ENRIQUE TOUCEDA,
Secretary.

EDITORIAL NOTE

The immediate revision of the Standard Specifications for Malleable Castings was approved at the annual meeting by a unanimous vote and was subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, page 491.

REPORT OF COMMITTEE A-10
ON
IRON-CHROMIUM, IRON-CHROMIUM-NICKEL AND RELATED ALLOYS

Two meetings of Committee A-10 have been held during the past year. This committee still consists essentially of a fact-finding and research group, and submits the following report of its activities:

The present membership of the committee is 47, five new members having been admitted during the year, of whom 19 are classed as producers, 21 as consumers and 7 as general interests.

GENERAL COMMITTEE ACTIVITIES

Coordination of the activities of Committee A-10 and Committee B-4 has been the subject of several conferences between representatives of the two committees and members of the Executive Committee of the Society. After careful consideration, it has been decided to change the title of Committee B-4 to read "Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys." The scope has been defined as: "Wrought and cast materials and parts for electrical heating and electrical resistance, and for the structure and containers of electric furnaces."

The title of Committee A-10 is: "Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys," and its scope: "Alloys as defined in title, not falling within the described scope of Committee B-4."

At the request of the Executive Committee a joint Advisory Committee of Committees A-10 and B-4 has been organized. The chairman and secretary of Committee A-10 have been appointed to represent the committee on this advisory committee. Two new subcommittees are in course of organization, namely, Subcommittee VI on Metallography, under the chairmanship of N. L. Mochel, and Subcommittee V on Mechanical Testing.

Because of the importance of welding the alloys falling within the scope of Committee A-10, a fact-finding committee consisting of four members, Messrs. Nelson, Olcott, Merica and MacQuigg, was appointed to survey the field. The committee has prepared a tabulated list of questions which has been sent to Mr. Merica for submission to the American Welding Society to determine whether work of this kind is now being undertaken and if not, the desirability of entering upon such studies.

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Classification of Data (Jerome Strauss, chairman).—Subcommittee I during the past year, engaged in a revision of the tables of composition and properties of corrosion-resisting and heat-resisting alloys, the original of which appeared as a part of a Symposium on Corrosion-Resistant, Heat-Resistant and Electrical-Resistance Alloys held in 1924.[1] In this work the subcommittee was, of course, greatly assisted by the various manufacturers, and in addition received the hearty cooperation of Committee B-3 on Corrosion of Non-Ferrous Metals and Alloys and also of *Chemical Catalog* and *Chemical and Metallurgical Engineering* who were engaged in similar tasks.

The data have been assembled in the form of insert tables appearing as Plates V to XV, bound at the back of this volume. The alloys, concerning which data are given, are grouped according to manufacturer, the manufacturers being listed alphabetically. It has been necessary to split the table in six parts with an (*a*) and (*b*) section of each part, section (*a*) giving the chemical compositions and physical properties, section (*b*) the corrosion-resistant properties.

The general arrangement of the data is very similar to that contained in the preceding tabulation prepared in 1924, but differs materially in that improved methods of reporting the mechanical properties at elevated temperatures and the corrosion-resistance properties have been employed. Because of these changes and the generally larger amount of information which manufacturers were able to provide, it is believed and hoped that the tabulation will prove to be of greatly enhanced value to the users of these metals and alloys.

Subcommittee II on Nomenclature (T. H. Nelson, chairman).—This subcommittee reports that there is nothing in the "Glossary of Definitions of Terms Appearing in A.S.T.M. Standards and Tentative Standards" prepared by Committee E-8 on Nomenclature and Definitions, that will conflict with the activities of Committee A-10.

Subcommittee III on Methods of Chemical Analysis (F. B. Foley, chairman).—This subcommittee has been considering the methods of analysis for chromium-nickel alloys described in the Tentative Methods of Chemical Analysis of Metallic Materials for Electrical Heating (B 71 – 29 T)[2] under the jurisdiction of Committee B-4 and find that further study of the problem is necessary before recommended practices can be adopted for alloys falling within the scope of Committee A-10.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 189 (1924).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 593 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 164.

Subcommittee IV on Methods of Corrosion Testing (W. R. Huey, chairman).—This subcommittee held several meetings during the year and has outlined the program for laboratory tests on four stainless alloys. The basic idea has been to purposely restrict activities for the time being to the inspection type of corrosion test. The alloys chosen for test are representative of those most generally used, namely: (*a*) 18 per cent chromium, 8 per cent nickel alloy; (*b*) 17 per cent chromium alloy; (*c*) 13 per cent chromium alloy with 0.08 to 0.12 per cent carbon annealed at 1300° F.; and (*d*) 13 per cent chromium alloy with 0.08 to 0.12 per cent carbon annealed at 1700° F.

Full details as to the composition and heat treatment of these alloys have been specified. Corrosion testing of the alloys has been restricted to three types of test, namely, the Du Pont acid-immersion test, the Navy Department salt-spray test, and the copper-sulfate stain test.

There have been requests by several interested parties for specific tests other than the three adopted, but the subcommittee has thus far not determined to expand its original plan at this preliminary stage, feeling that the general program should not be encumbered with too many testing activities. For the present, the work undertaken by the subcommittee is designed to determine the agreement that may be expected of different laboratories testing under the same conditions and to develop information of greatest value to the largest number of users of the alloys; this should be possible if the program is restricted to inspection testing, using a small number of representative tests and alloys. It is hoped that the ultimate results will be of value chiefly to a large number of small users, rather than to large consumers, who usually have varied facilities for thorough testing of raw materials.

The amount of steel required for the test is quite large and has been graciously donated by the manufacturer members of the committee. At the present time, the steel is made and is awaiting distribution to the laboratories which will participate in the test. Arrangements are being made with 14 laboratories to make the tests, using the three methods specified.

The election of officers held during the Detroit meeting, March 19, resulted in the selection of the following for the ensuing term of two years:

Chairman, Jerome Strauss;
Vice-Chairman, T. H. Nelson; and
Secretary, H. D. Newell.

This report has been submitted to letter ballot of the committee, which consists of 47 members; 40 members have returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

JEROME STRAUSS,
Chairman.

H. D. NEWELL,
Secretary.

REPORT OF RESEARCH COMMITTEE
ON
FATIGUE OF METALS

The activities of this committee during the past year have been concerned with two projects: (1) the preparation of abstracts of important articles and books dealing with the fatigue of metals, and (2) the preparation of a brief statement of the present status of knowledge and current theory in the field of fatigue of metals.

The abstracts of important publications both in this country and abroad which were important contributions to the fatigue of metals were prepared by the various members of the committee, and a pamphlet covering the period from July 1, 1928, to July 1, 1929, was issued in October. This pamphlet was noted in the *Bulletin* of the Society, and the Secretary-Treasurer reports that the demand for it was as great as for almost any paper or report published during the year. The committee plans to compile another pamphlet of abstracts covering the period from July 1, 1929, to July 1, 1930.

In preparing a statement summarizing knowledge and current theories as to fatigue of metals the committee realizes that it is putting out material much of which will be of temporary character.

Developments are taking place so rapidly that only the barest mention of general tendencies seems possible at this time. This summary is submitted as an Appendix to this report.

As this is a research committee and not a committee for making specifications it is not planned to prepare standards. The committee, however, is hoping to publish from time to time comments on satisfactory and unsatisfactory methods of fatigue testing and will always be glad to cooperate with any of the standing committees of the society that may wish to introduce values of fatigue strength into its standards.

Respectfully submitted on behalf of the committee,

H. F. Moore,
Chairman.

APPENDIX

PRESENT-DAY EXPERIMENTAL KNOWLEDGE AND THEORIES OF FATIGUE PHENOMENA IN METALS

INTRODUCTION

The following sections comprise brief notes summarizing present-day views regarding fatigue phenomena in metals. It has been attempted to give concise presentations rather than comprehensive ones. Different members of the Research Committee on Fatigue of Metals have prepared the several sections, an attempt having been made to assign each section to a member whose special interests have brought him into contact with that particular phase of fatigue of metals.

The committee realizes that this summary by no means covers the field completely and that it is mainly a gathering together of the views of individuals. The sections have been submitted to all the members of the committee for criticism before publication.

It is not within the province of a research committee to suggest definitions to be adopted as standards by the Society, but in order to explain the meanings of several terms as used in this appendix the following definitions are given:

Fatigue of Metals.—The phenomenon of the progressive fracture of a metal by means of a crack which spreads under repeated cycles of stress. The use of the term "fatigue" has, unfortunately, become fairly well fixed in our technical vocabulary. "Progressive fracture" would be a better term than "fatigue of metals."

Endurance Limit.—A limiting stress, below which metal will withstand without fracture an indefinitely large number of cycles of stress. If the term is used without a qualifying adjective the cycles of stress are usually such as to produce complete reversal of flexural stress.

Fatigue Limit.—Usually used as synonymous with "endurance limit." It has been proposed to use the term fatigue limit to denote a limiting stress for a given specimen as distinct from the endurance limit of the metal, but this usage has not been widely adopted.

Endurance Ratio.—The ratio of endurance limit for cycles of reversed flexural stress to the tensile strength of the metals.

ENDURANCE LIMIT, MACHINES, SPECIMENS, AND ACCELERATED TESTS

BY R. R. MOORE[1]

DETERMINATION OF ENDURANCE LIMIT

To determine the endurance limit of a metal it is necessary to prepare a number of similar specimens which are thoroughly representative of the material. The first specimen is tested at a relatively high stress so that failure will occur at a small number of applications of stress. Further tests are then made each time at a lower stress, and the number of repetitions required to produce failure will increase as the stress decreases, until a stress is reached at which the specimen has an exceedingly long life.

If the test results obtained in this manner are plotted with the values of the stresses as ordinates and the number of repetitions to failure as abscissas, it will be found that the curve takes the form shown in Fig. 1. If, however, the values of stress, S, and values of repetitions, N, are plotted to logarithmic or semi-logarithmic coordinates the result is an SN diagram which often approximates a straight line above the fatigue limit.

The original curve plotted to semi-logarithmic coordinates is shown in Fig. 2. Endurance tests are now plotted either by the logarithmic or, more commonly, semi-logarithmic methods and such graphs are known as S-N diagrams, "endurance curves," or stress-cycle diagrams.

The S-N diagram is shown here as two straight lines, a sloping line and a horizontal line joined by a slightly curved "knee." In some cases the sloping line has been found to take a slight curvature, upward concave, and in a few cases a reversal of curvature has been recorded. The horizontal part of the curve would indicate that a stress has been reached at which it will require an enormous number of repetitions of stress to produce failure, or probably it will never fail. The last four points in Fig. 2 show that the specimens have not failed at 100,000,000 repetitions of stress.

In order to determine the endurance limit then, it is necessary to run sufficient tests to establish the "knee" on the endurance curve. It will be noted that in the particular S-N curve shown, the knee occurs at $N = 1{,}000{,}000$. On some steels the knee is not obtained until $N = 10{,}000{,}000$ is reached. In no case, however, has N been located at greater than 10,000,000 on ferrous metals. Long-time tests run by H. F. Moore at the University of Illinois have established the fact that a steel which will withstand 10,000,000 repetitions of a certain stress will not fail within 100,000,000, and he has gone so far as to show in at least one case that this can be extended to 1,000,000,000 repetitions of stress.

The values quoted above for locating the knee in the S-N curve, or what amounts to the same thing, the value for the endurance limit, does not hold for non-ferrous metals. R. R. Moore has shown that for manganese bronze the knee occurs at 13,000,000 and for elektron metal at about 28,000,000 repetitions. He has also shown that certain duralumin specimens give no indication of having reached an endurance limit up to 400,000,000 repetitions of stress.[2] Gillett did not find an endurance limit for naval brass at 50,000,000 and H. F.

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[1] Chief Metallurgist, Wright Aeronautical Corp., Paterson, N. J.

[2] Johnson and Oberg(46) found no clearly defined endurance limit for duralumin at 500,000,000 cycles.

Moore did not find one clearly defined for a certain sample of monel metal at 750,000,000 repetitions. On the other hand, R. R. Moore located an endurance limit for extruded magnesium-base alloys at 600,000 repetitions. Evidently the non-ferrous metals do not, as a class, follow any general law as is the case with ferrous metals. It should be carefully noted, however, that it is characteristic of non-ferrous metals to fail after exceedingly long runs, and this feature should be given due consideration in studying the properties of these metals and also in their application in machines and structures.

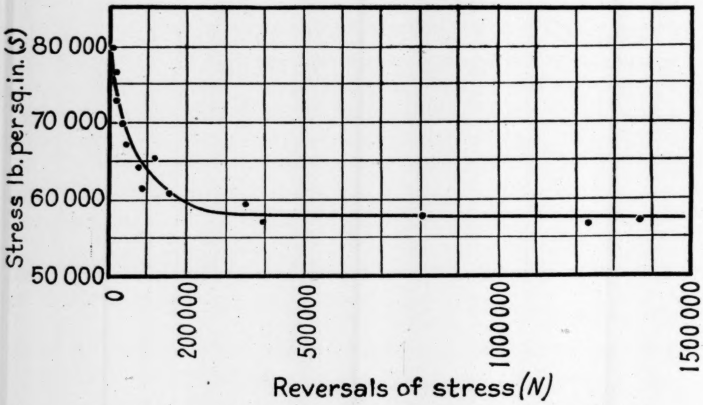

FIG. 1.—Typical S-N or Stress-Cycle Diagram for a Fatigue Test. Cartesian plotting.

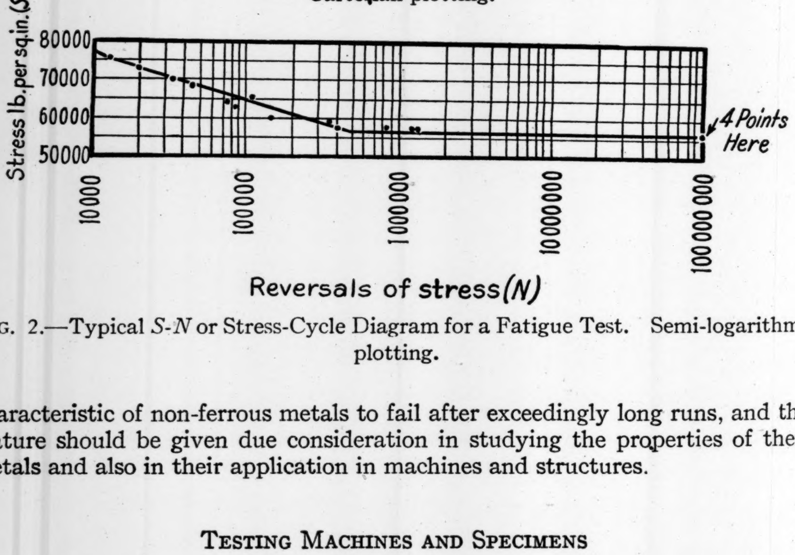

FIG. 2.—Typical S-N or Stress-Cycle Diagram for a Fatigue Test. Semi-logarithmic plotting.

TESTING MACHINES AND SPECIMENS

Testing machines for determining the endurance limit of metals are of various types and forms depending upon the type of stress which they are called upon to develop. They may be classified into three general types: (1) direct tension-compression; (2) flexure or bending; (3) torsion or shear. These classifications may be again subdivided as to the methods of developing the stress in the specimen, as (*a*) constant stress machines; and (*b*) constant

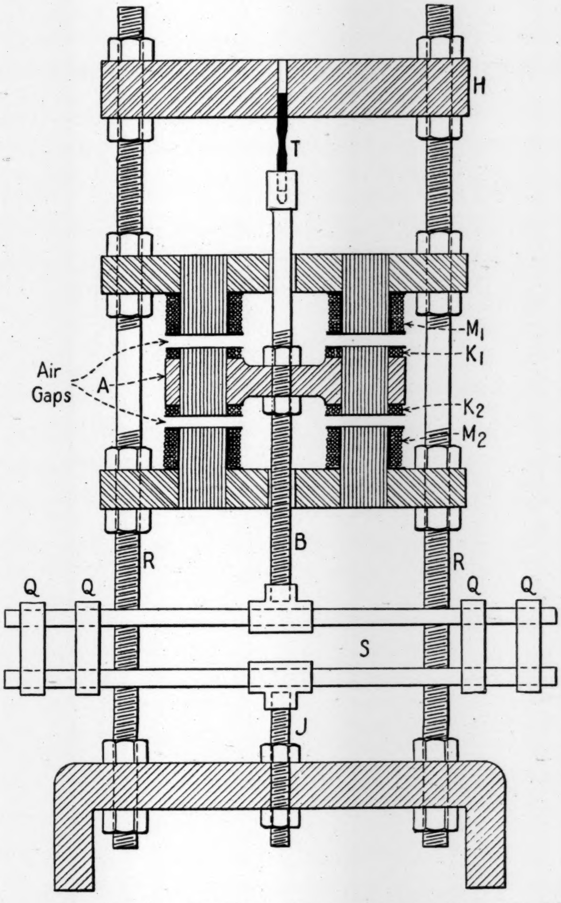
H
T
M_1
K_1
Air Gaps
A
K_2
M_2
B
R
R
Q
Q
Q
Q
S
J

FIG. 3.—Haigh Direct Tension-Compression Fatigue Machine.

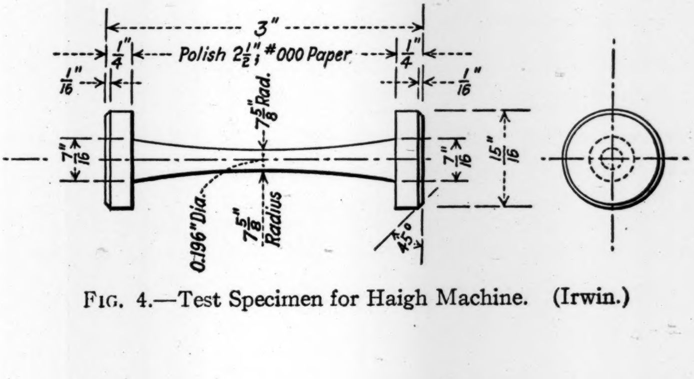
3"
1/4"
Polish 2 1/2", #000 Paper
1/4"
1/16"
1/16"
7 5/8" Rad.
7/16"
7/16"
15/16"
0.196" Dia.
7 5/8" Radius
45°

FIG. 4.—Test Specimen for Haigh Machine. (Irwin.)

strain machines. In the constant stress machine the stress is uniform throughout the test right up to the instant of failure but in some cases the specimen may yield near the end of the test and take on a greater deformation. In the constant stress machine the stress is computed from the loads applied to the specimen. In the constant strain machine the deformation of the specimen is uniform throughout the test. If there is a tendency for the specimen to yield near the end of the test the deformation in the specimen can not increase but the tendency to yield may result in a lowering of the actual stress due to readjustments in the metal. The stress is usually computed from measurements of deformation of the specimen.

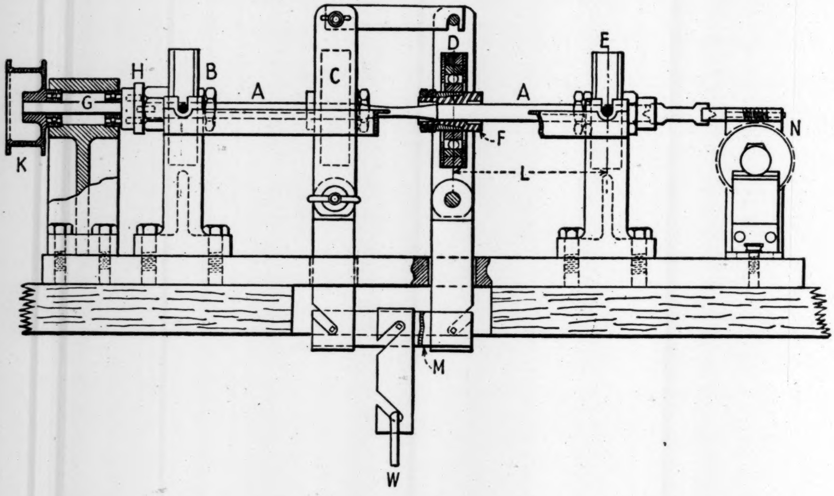

FIG. 5.—Long-Specimen Rotating Beam Fatigue Machine. (Sondericker or Farmer Type.)

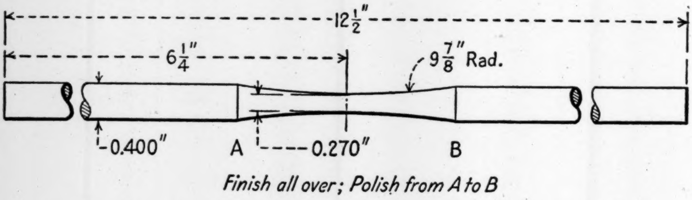

FIG. 6.—Test Specimen for Long-Specimen Rotating Beam Machine. (H. F. Moore.)

Direct Tension-Compression Machines:

The direct tension-compression machine has been the most difficult to develop, because of the difficulty in producing uniformly distributed axial loading. While many investigators have produced machines which perform satisfactorily in their own hands due to their thorough understanding of the peculiarities of these machines, the Haigh machine, shown in Fig. 3, is the most widely used commercial machine. The specimen recommended for use with this machine is shown in Fig. 4.

The Haigh machine is the electro-magnetic type. The specimen, T, is attached at one end of the framework of the machine and the other end of the specimen is attached to a cross-head holding an armature, A. The armature is set between two magnets, M_1 and M_2. These magnets are energized by alternating current which alternately attracts and repels the armature and thus causes the specimen to be stretched and compressed. The load applied to the specimen is determined from voltmeter readings on the secondary coils, K_1 and K_2. These readings have to be calibrated in pounds from a calibration bar supplied with the apparatus, which bar must in turn be standardized in a static testing machine. The spring, S, is necessary in order to keep the machine tuned so that the armature acts in unison with the magnetic pull. The speed of this machine is about 2400 reversals per minute.

When properly calibrated and adjusted the Haigh machine is very satisfactory. It is recommended that the refinements as to methods of holding the specimen, calibrating the machine and design of test specimens as developed by P. L. Irwin(**42**)[1] be carefully investigated by those who consider using the Haigh machine.

Flexure or Bending Machines:

Machines for bending or flexural stresses are the most common types used and have been used in more than 90 per cent of the fatigue tests made. The popularity of this type of machine is due to its simplicity of operation, the accuracy with which it can be calibrated and the fact that it produces a condition of stress that is very commonly met in engineering practice. For the test of cylindrical specimens these machines may be divided into two classes: (1) simple rotating beam; (2) cantilever rotating beam. The simple rotating beam machine is made in two modifications, (*a*) the long-specimen type; (*b*) the short-specimen type.

Long-Specimen Rotating Beam Machine.—The long-specimen type is sometimes referred to as the Sondericker or Farmer machine a model of which developed by H. F. Moore is shown in Fig. 5. In this type of test the specimen acts as a simple beam loaded at two points in the manner indicated, and it is rotated while under load. From an examination of the bending moment diagram of such a beam it is evident that the bending moment is uniform between the load points. If the cross-section of the specimen is uniform between these load points then the stress in the specimen will be uniform over this portion of the specimen. The stress is computed from the formula:

$$S = \frac{16\,WL}{\pi\,d^3}$$

where S = extreme fiber stress,
W = load hung from specimen,
L = moment arm (distance from end support to load point), and
d = minimum diameter of specimen between loads.

Due to the concentration of stress set up by the clamping collets at the points where the load hangers are attached, the specimen will break there prematurely unless precautions are taken to prevent this. This difficulty is overcome by gradually reducing the cross-section of the test specimen between the load points as is indicated in Fig. 5 and again in the detail of the test specimen as shown in Fig. 6. In making this reduction it is very important that the transition from the large to the small cross-section be made very gradually, as small radii or fillets will influence the location and time of the failure due to concentrated stresses. Experiment has shown that specimens made to the form of Fig. 6 which indicates a large radius of curvature in the reduced section will be free from stress concentration. The actual stress at the minimum section of a specimen as shown checks very well with the value computed by

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[1] The boldface numbers in parentheses refer to the reports and papers given in the list of references, see p. 305.

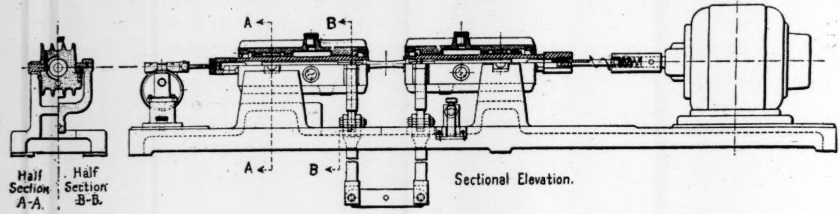
A
B
A
B
Half Section A-A.
Half Section B-B.
Sectional Elevation.

FIG. 7.—Short-Specimen Rotating Beam Fatigue Machine. (R. R. Moore.)

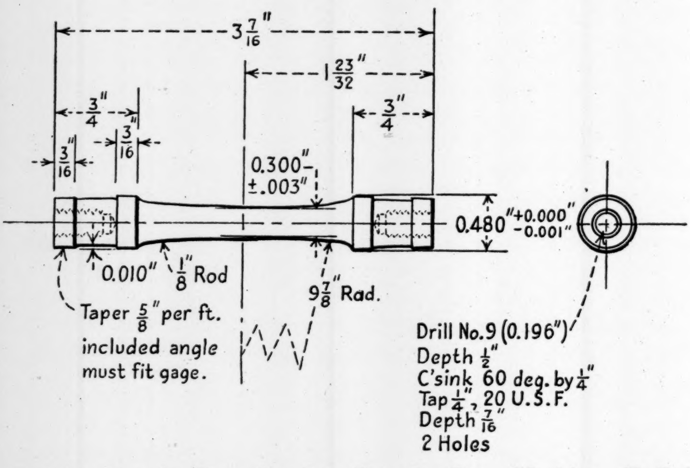
3 7/16"
1 23/32"
3/4"
3/4"
3/16"
3/16"
0.300" ±.003"
0.480" +0.000" -0.001"
0.010"
1/8" Rod
9 7/8" Rad.
Taper 5/8" per ft. included angle must fit gage.
Drill No.9 (0.196")
Depth 1/2"
C'sink 60 deg. by 1/4"
Tap 1/4", 20 U.S.F.
Depth 7/16"
2 Holes

FIG. 8.—Test Specimen for Short-Specimen Rotating Beam Machine. (R. R. Moore.)

means of the formula. It is recommended that the shape of the specimen as shown be adhered to closely if dependable results are desired.

It should be noted particularly that in this type of test the stress is not uniformly distributed over the cross-section of the specimen but varies from a maximum at the outer fibers to zero at the neutral axis. The fibers at the top of the specimen are in compression and the fibers at the bottom are in tension. When the specimen is rotated one-half revolution this condition is reversed; the fibers that were in tension now are in compression and *vice versa.* Thus with each revolution the specimen is subject to a complete cycle of reversed stress from tension to compression.

Short-Specimen Rotating Beam Machine.—In the short-specimen type of rotating beam machine, the portions of the specimen between the load points and the end supports are replaced by two spindles. The test specimen is only of sufficient length to extend between the load points, but this is all that is necessary for it represents the only portions of the long specimen that is actually under test. This scheme has been used by Ono, by H. F. Moore and R. R. Moore in ball bearing type machines and also by R. R. Moore in a plain bearing type machine as shown in Fig. 7. It is evident that the conditions of stress developed in the specimen are the same as described for the long specimen type, namely, a complete cyclical reversal of flexural stress. The value of this stress is computed from the same formula.

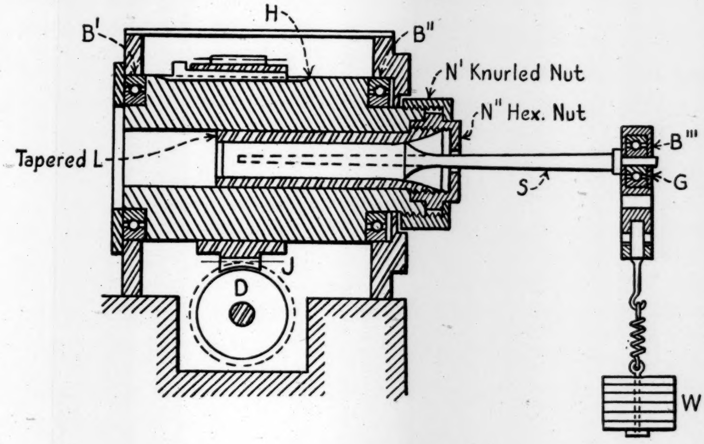

FIG. 9.—Cantilever Rotating Beam Fatigue Machine. (D. J. McAdam, Jr.)

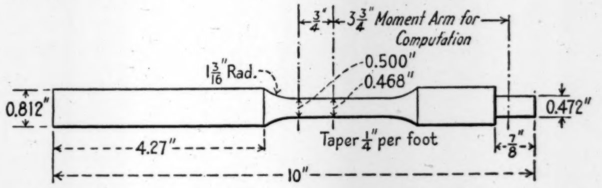

FIG. 10.—Test Specimen for Cantilever Fatigue Machine. (D. J. McAdam, Jr.)

The test specimen is shown in Fig. 8 and it will be noted that the same radius of curvature at the reduced section has been used as was found to be satisfactory on the long specimen in Fig. 6. This design of short specimen has proved to be very satisfactory.

The short specimen type machine offers certain advantages over the long specimen type of machine. In the first place this machine is more accurate, because the moment arms (distance from end supports to load points) are accurately and permanently fixed when the machine is built and are never varied, regardless of shape or size of specimen. In the long specimen type machine (Fig. 5) the moment arm is reset for every test specimen placed in the machine and even though jigs may be used to make this set up there is considerable opportunity for error. The short specimens are a necessity when it is desired to take samples from parts of machines or structures. When testing soft materials such as aluminum or magnesium, the short specimen overcomes a serious difficulty encountered both in machining the long specimen and in setting up the machine without deforming the specimen. So far as the plain bearing feature is concerned it is generally conceded that this type is smoother running than the ball bearing type and thus reduces to a minimum the additional unknown stresses which might have serious effects on the test results.

Cantilever Rotating Beam Machine.—The cantilever machine is shown in Fig. 9. It is the typical overhanging beam, the bending moment varying from zero at the load point to a maximum at the support and for a specimen of uniform cross-section the stress varies likewise. The stresses produced in this specimen are the same as described for a long specimen rotating beam machine, namely, a complete cyclical reversal of flexural stress. The stress is computed from the formula:

$$S = \frac{32\,WL}{\pi\,d^3}$$

The first commercial type of machine of this design was known as the White-Souther. Various investigators have added refinements which considerably improve the operation of the machine. Those who may have a particular reason for using this type are recommended to adopt the improvements as developed by D. J. McAdam, Jr.,(58) who has been quite successful in obtaining uniform and reliable test results by the use of certain modifications.

Reversed Plain Bending Machine.—For tests on flat stock and sheet metal, a machine which produces plain bending is commonly used. The most successful machines for this type of test have been developed by individual investigators. In most cases these machines have been of the constant strain type in which the stress in the specimen is computed from measurements of deflection. The number of machines of this type that have been developed are too numerous to be described here. The designs described by Moore and Kommers(74) are highly recommended for a large variety of work. For tests on very soft or very thin sheet the designs developed by J. R. Townsend (108, 109) are highly recommended.

Torsion Testing Machines:

Most repeated torsion testing machines develop a condition of shearing stress alternately reversed in direction. The stress is uniformly distributed over the length of the specimen but varies over the cross-section from a maximum at the outer surface to zero at the center of the bar. The stress at the outer surface is computed from the formula:

$$S_s = \frac{16\,M}{\pi\,d^3}$$

where S_s = extreme fiber stress in shear, in pounds per square inch,
M = twisting moment, in inch-pounds,
d = diameter of the specimen, in inches.

A number of types of these machines have been developed and they will be found described in detail in Moore and Kommers (74) and by Hankins (37).

Combined Stress Machines:

A number of machines have been developed to produce combinations of stress such as reversed flexure superimposed on a direct stress or a combination of reversed flexure and reversed torsion. The machines for producing these conditions of stress in the specimen are not available in the market so that the reader is referred to Moore and Kommers(74) and H. J. Gough's book on Fatigue of Metals(22) in which several types of these machines are described.

Summary of Test Machines:

The simple and cantilever rotating-beam types of machines have been given considerable space in this report for the reason that they can be obtained commercially and are in common use. There is a difference of opinion as to which machine is most desirable. For soft materials and when specimens are to be taken from structural members the short specimen rotating beam is preferable. For very large specimens such as axles there may be an advantage in the cantilever type. It is only in the case of special problems such as thin and soft sheet metal, torsion and combined stresses that it is necessary to use the more or less special fatigue machines referred to in this report.

Finish on Test Specimens:

In making fatigue tests it is very necessary that the surface of the specimen be smooth and free from scratches. The presence of scratches produces intensified stresses and thus affects the test results. Steel specimens should be finished with very fine emery cloth, at least the No. 00 grade, in order to remove all the scratches produced by previous operations. Specimens made of soft metals as aluminum and magnesium must be finished more carefully. Satisfactory results can be obtained by finishing with No. 000 Manning paper or its equivalent. A satisfactory way of insuring that all serious scratches have been removed is to finish to a bright surface with No. 65 levigated alumina. The bright surface causes any serious scratches to stand out sharply in contrast so that they are easily detectable. Polishing should be done by moving the abrasive in a direction parallel to the axis of the specimen rather than across it in order that the scratch effects be minimized.

In machining test specimens it is advisable to cut them with a sharp tool using a light cut and slow speed. Forming tools should not be used because they distort the surface of the specimen and thus affect the test results. Flat specimens should never be sheared or punched out.

ACCELERATED ENDURANCE TESTS

A fatigue machine running at 1500 r.p.m. will make 2,160,000 repetitions of stress in a twenty-four hour day. In the testing of ferrous alloys it will be sufficient to run a specimen to 10,000,000 repetitions in order to determine whether the endurance limit has been exceeded. This will take about four and one-half days. As it will be necessary to run several tests in order to locate the endurance limit it is evident that the amount of time consumed or the duplication of machines necessary is considerable. In order to shorten the time of test, various types of accelerated tests have been investigated. Among these are (1) examination of the hysteresis loop; (2) magnetic exploration; (3) rise of temperature; (4) change in rate of deflection method.

Each of these methods has been shown to be inapplicable to all metals. The rise of temperature and change in rate of deflection methods are only fairly satisfactory on wrought ferrous metals and fail to indicate correctly the endurance limit of a number of non-ferrous metals. The rate of deflection method has been shown to give erroneous results on damaged specimens and on high tensile strength steels. The magnetic method has given erroneous results due to release of internal stress during the test.

From our present knowledge of the nature of fatigue failure, it would appear that a satisfactory accelerated endurance test must be sensitive to any nucleus that could develop into a crack that will propagate and ultimately cause a failure in a long-time endurance test. There appear to be but two methods so far suggested that are logical accelerated tests from this point of view.

One of these methods is the inertia type of testing machine, such as that of McAdam(60) in which, when failure starts, the deflection and the load both increase. Stress does not increase until either slipping or incipient cracking starts, but then increases, and thus hastens failure. However, this method will not necessarily work in the cases where slip can occur at stresses that will not cause failure. It should give safe but not necessarily true results.

The other is the Ikeda(40, 75) method which is designed to tell when actual cracking starts. As incipient cracking is the forerunner of fatigue failure, this Ikeda method is based on sound theory, the detection of the development of a crack by noting a change in the electrical resistance of a specimen. The only question is whether it is sensitive enough to detect an *incipient* crack, the development of which may be so long delayed as to require many millions of cycles before failure. It has promise and is worth more research but has not been sufficiently tested, on slightly over-stressed specimens for example, to allow this committee to recommend it as yet for general use as a reliable substitute for the regular, slow method of determining the *S-N* diagram.

A very obvious method of shortening the time in obtaining fatigue test results is to speed up the ordinary endurance test. Up to 5000 cycles per minute the speed does not appear to affect the test results. At extremely high rates of speed conflicting results have been obtained. The work of Jenkins and Lehman(45) indicates that the endurance limit is increased at these high speeds while the work at the Bureau of Standards indicates that it is decreased.

CORRELATION OF ENDURANCE LIMIT WITH OTHER PHYSICAL PROPERTIES

BY J. R. TOWNSEND[1]

Correlation between the endurance limit of a metal subjected to repeated flexural stress and some one or more of the other more readily determined physical properties is most desirable because of the expense involved and the time required to determine the endurance limit by a long-time test. If some definite relationship can be found so that the endurance limit of a metal may be defined in terms of other physical properties then fatigue data readily become available for use in engineering design.

There is no direct relationship between the endurance limit and any of the other physical properties which will hold for all metals. In the field of non-metallic materials so little work has been done on fatigue testing that correlation of any sort is most difficult. The results of many tests by numerous investigators indicate that the tensile strength, the Rockwell and the Brinell hardness numbers, the modulus of rupture (for cast metals) and the change in electrical resistance bear the most consistent relationship to the endurance limit as obtained from long-time fatigue tests. In steel, according to Gillett(16), there is a broad generalization that the endurance limit for completely reversed stress is pretty nearly directly proportional to the tensile strength or the Brinell hardness number, being roughly one-half of the tensile strength. This relationship does not hold for steels having a Brinell hardness greater than 400. Outside of the field of wrought ferrous metals there is practically no correlation with strength or hardness. This is confirmed by R. R. Moore(79), Townsend and Greenall(109), and others who found that the endurance limit of the non-ferrous metals does not bear any definite relation to the other physical properties.

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[1] **General Development Laboratory, Bell Telephone Laboratories, Inc., New York City.**

Moore and Konzo(75) state that the difficulties with all of the tests previously made to correlate the endurance limit with results of short-time tests—with possible exception of the power input method and the change in electrical resistance methods—are that they detect slip rather than the starting of the fatigue crack. Haigh's(32) experiments have shown that no clear relation is at present known to exist between the beginning of slip and the start of a fatigue crack. In the case of ferrous metals, slip seems to precede the starting of a fatigue crack and to occur at a stress a little below that corresponding to the starting of this crack, whereas in the case of certain non-ferrous metals a fatigue crack apparently starts before there is any appreciable amount of slip(78). To further complicate the correlation between fatigue failure and the short-time tests, many non-ferrous metals show endurance limits considerably higher than the proportional elastic limit, in which case a considerable amount of slip precedes any tendency to fatigue failure. Moore and Kommers(74) state that it is not to be expected that there will be found any precise correlation between fatigue strength and any one other physical property of a metal. Probably elastic strength, tensile strength and ductility all have an effect on the fatigue strength. Fatigue failure, however, seems to be a progressive failure, a fracture of a metal, and it is not surprising that there seems to be closer correlation between fatigue strength and tensile strength than there is between fatigue strength and any other one physical property.

In the following paragraphs may be found a brief discussion of the relation of fatigue strength to various physical properties and short-time tests.

Tensile Strength.—For wrought ferrous metals the fatigue strength is approximately one-half of the tensile strength according to Moore and Kommers(74), the range being from 40 to 60 per cent. This is confirmed by Gough(22), who states that the ratio of fatigue strength to tensile strength is on the average 0.46. McAdam(59), however, found this ratio to vary, not only with the chemical composition but also according to the microstructure of the steel.

For cast ferrous metals the fatigue strength is approximately 40 per cent of the tensile strength(74).

For non-ferrous materials no definite relationship exists, the fatigue strength varying from 18 to 50 per cent of the tensile strength(109).

Proportional Elastic Limit.—There is no direct relationship between the static proportional limit and the endurance limit for completely reversed stress(109, 16). This is confirmed by investigations made at the U. S. Naval Engineering Experiment Station, the Illinois Engineering Experiment Station, the National Physical Laboratories and elsewhere.

Yield Point.—No general relation exists between the fatigue strength of a steel and the yield point, the ratio varying from 1.31 to 0.53(22).

Brinell Hardness.—For wrought ferrous metals below 400 Brinell, the fatigue strength is approximately 250 times the Brinell hardness number. This relationship fails to hold when the Brinell hardness is in excess of 400.

For cast ferrous metals and non-ferrous metals insufficient data are available for correlation.[1]

Rockwell Hardness.—Because of the relationship which exists between tensile strength and Rockwell hardness, correlation may also be obtained between fatigue strength and Rockwell hardness. This relationship will not be a simple one because the Rockwell hardness - tensile strength curve approximates a straight line only over a portion of its length. Few data are available on this correlation.

Ductility and Reduction of Area.—No correlation exists between reduction of area—an index of ductility—and the fatigue strength. The ductility of a metal also appears to have little effect on the ratio of fatigue strength to tensile strength. It is possibly a major factor in determining fatigue strength in regions of localized high stresses.

Modulus of Rupture.—For cast ferrous metals the fatigue strength may be considered as approximately 0.26 per cent of the modulus of rupture. For other metals and materials data for correlation are lacking(**48**).

Change in Modulus of Elasticity.—Some work has been done by Richardson(**88**) which indicates that this method may be developed into one of usefulness. Too few data on change in modulus are available at present. Further work along these lines may prove of interest.

.*Charpy Impact and Repeated Impact.*—Gillett and Mack(**17**) found no relation between the fatigue strength of a metal and either single or repeated impact tests. This lack of correlation is likewise reported by Gough(**22**) and Moore and Kommers(**74**).

Metallographic and X-ray Spectrographic Methods.—These methods have so far shown no promise of telling when fatigue failure starts.

Cold Work.—Correlation between the amount of cold work and the fatigue strength of a metal is lacking.

Elastic Hysteresis.—Elastic hysteresis can only be regarded as a symptom of an action which may or may not lead to fatigue.

EFFECT OF RANGE OF STRESS AND KIND OF STRESS ON FATIGUE STRENGTH

BY J. B. KOMMERS[2]

Range of Stress:

The great majority of results obtained hitherto from fatigue tests have been determined by some form of rotating-beam test, in which the specimen was subjected to completely reversed tensile and compressive bending stresses. The reason that this test has been so commonly used is because it has been comparatively easy to devise a machine for making the test, and at the same time enable the intensity of stress to be computed with a very good degree of accuracy.

There are numerous cases in structural and machine parts in which the members are not subjected to completely reversed stresses. In such cases the stresses may fluctuate between upper and lower limits of the same kind of stress, or they may be partly reversed.

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[1] It should be noted that Brinell hardness number is measured in kilograms per square millimeter, and endurance limit in pounds per square inch.

[2] Professor of Mechanics, Engineering College, University of Wisconsin, Madison, Wis.

To determine a range-of-stress diagram rather completely it is evidently necessary to choose various ratios of minimum to maximum stress and determine the endurance limit of the material for these "range ratios." It is obvious that a considerable number of tests are necessary to determine a range-of-stress diagram, even when a suitable machine is available.

Suitable machines for carrying out such tests are not nearly so simple as those required for a rotating-beam test. After a machine has been developed for applying the load to the specimen, the task is only half done, because it is necessary to make sure that no stresses are applied to the specimen other than those used in calculating the intensity of stress. This is well illustrated by the machines which have been developed for applying axial loads in tension and compression. Many of the results reported in the past on range of stress, have been incorrectly reported because of the fact that the specimen was subjected to bending stresses of unknown amount during the compressive part of the cycle.

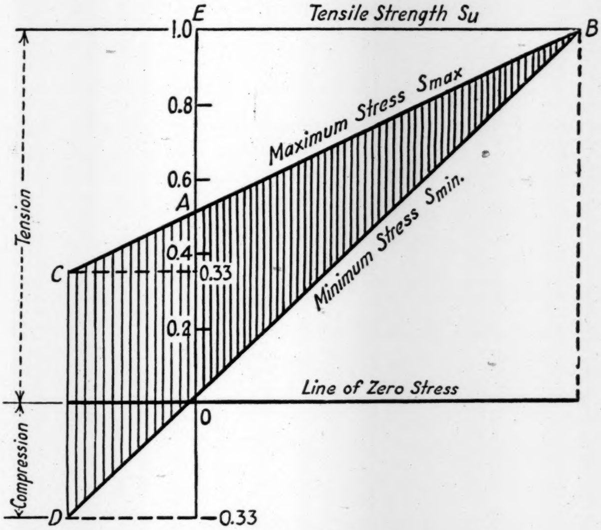

FIG. 11.—Goodman Diagram for Range of Stress.

This statement is substantiated by the results reported by Irwin(42) in 1925 and 1926. Irwin was extremely careful in his design of the method for applying the compressive load. The result was that he found that the endurance limits obtained in the axial stress tests were practically the same as those obtained in the rotating-beam tests. This was in sharp contrast with results reported by previous experimenters, who had found that the endurance limit under axial stresses was considerably less than under flexural stresses. Irwin's tests indicated that when the endurance limits under axial stress had been found less than under flexural stress, the axially loaded specimens had been eccentrically loaded during the compressive part of the cycle. Under such conditions the specimen would be subjected to bending stresses of unknown amount in addition to the computed axial stress. The author feels no hesitation in saying that in any tests on range of stress using axial loads it is absolutely essential

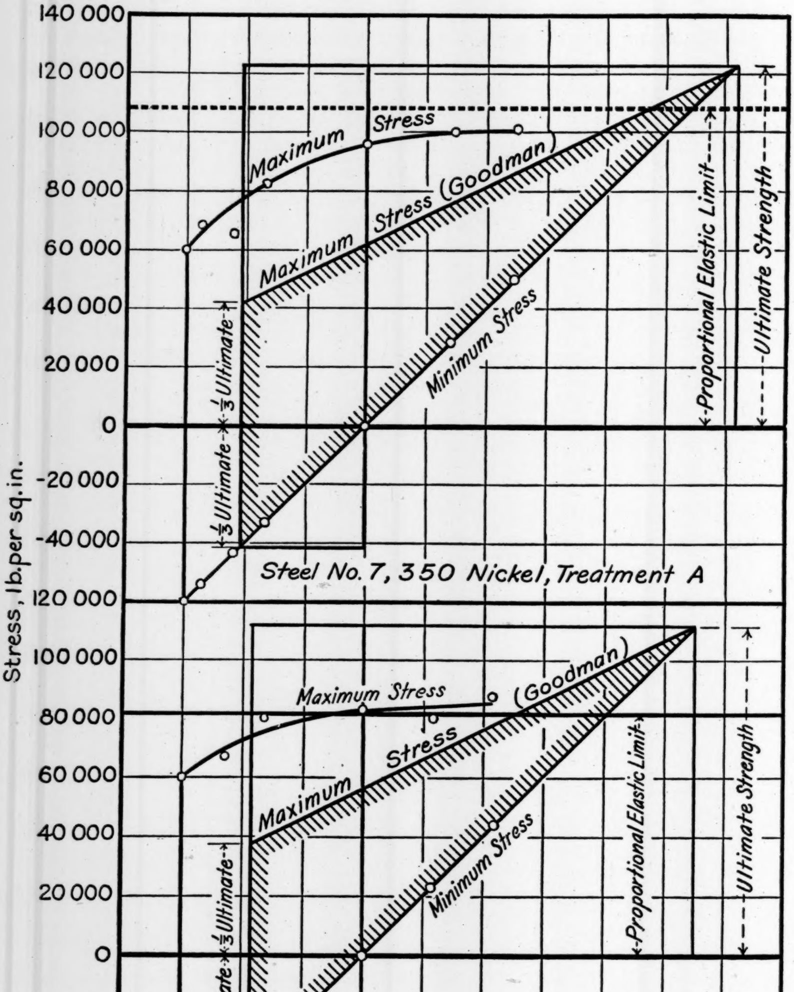

FIG. 12.—Comparison of Experimental Results with Goodman's Diagram for 3.5-per-cent Nickel Steel. (*Bulletin No. 136*, Engineering Experiment Station, University of Illinois.)

to give careful attention to getting truly axial loading in the compressive portion of the cycle.[1]

Moore and Jasper(69) have reported some tests on range of stress in which the specimen was subjected to an axial tension combined with a reversed flexure. These tests will be discussed later.

One of the important pieces of work in fatigue testing which still remains to be done is a comprehensive series of tests to determine accurate diagrams of range of stress for a variety of materials.

Range-of-Stress Diagrams:

Range-of-stress diagrams may be plotted in a number of ways. The diagram suggested by both Goodman and J. B. Johnson is probably the simplest and the one which is most easily interpreted. Figure 11 shows this diagram. The ordinate of the line *EB* represents the static tensile strength of the material. The minimum stresses are plotted along a 45-deg. line *DOB*. The horizontal line through *O* is the line of zero stress, tensile stress being plotted above the line and compressive stress below it. According to the "dynamic theory" of suddenly applied loads,(19, 9) the minimum or dead load stress plus *twice* the live load stress equals the static ultimate strength; and the maximum applied stress should fall on a line *CAB*, such that the point *A* is five-tenths of the ultimate static strength. Goodman plotted endurance limits obtained by various investigators after the material had been subjected to over 4,000,000 cycles of stress, and found that these experimental points fell fairly well on the straight line *CAB*.

As the diagram shows, when the minimum stress is zero the maximum stress for indefinite endurance should be five-tenths of the ultimate static strength. When the stress is completely reversed at *CD*, the plus and minus stresses should be one-third of the ultimate strength. Presumably a diagram similar to the one shown in Fig. 11 would hold when the stress above the zero line is compressive and that below is tensile. Experimental data, however, are very meager for these combinations of compressive stress.

According to the Goodman diagram, the range of stress (algebraic difference between maximum and minimum) is greatest for reversed stresses and decreases as the maximum stress is increased above one-third of the ultimate strength, being actually zero when the maximum stress coincides with the ultimate. In other words, as the maximum stress is increased, the minimum stress must also be increased algebraically in order that the material may be stressed indefinitely without fracture.

Figure 12 shows range of stress diagrams obtained by Moore and Jasper on nickel and carbon steels.(69) These results were obtained on a machine which subjected the specimen to a steady axial tension combined with reversed bending. These diagrams indicate, in general, that the experimental results for maximum stress lie higher than those given by the Goodman diagram. This would indicate that, in general, the results shown by the Goodman diagram are on the side of safety. This statement is to be taken as applying to ferrous metals and alloys.

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[1] Pure axial stress free from bending is very difficult to obtain in actual machine parts. Probably in design formulas, allowance should be made for this.

Figure 13 shows the results obtained by Haigh(30) on a 60-40 brass. Haigh did not carry his tests beyond 2,000,000 cycles, and later tests have shown that this would not be sufficient to determine the endurance limit accurately. This being the case, the values given by Haigh for endurance limits would be somewhat too high. Figure 13 shows that the results are in fairly good agreement with the form of the Goodman diagram.

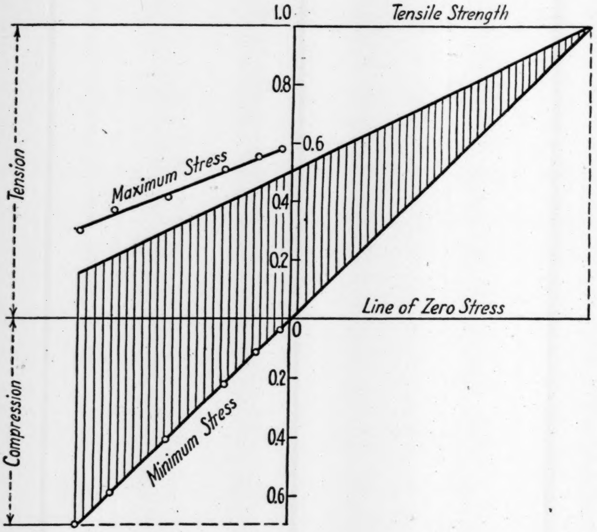

FIG. 13.—Haigh's Results on Brass.

Formulas for the Goodman Diagram.—J. B. Johnson developed a formula for the Goodman-Johnson diagram, which was afterwards simplified by Barr:

$$S_{max} = \frac{0.5\ S_u}{1 - 0.5r} \quad \text{.......................(1)}$$

where S_{max} denotes the maximum stress during any cycle, in pounds per square inch,

S_u denotes the static tensile strength of the material, in pounds per square inch,

r denotes the range ratio, or the ratio of the (numerical) minimum stress to the maximum for any cycle. It should be noted that the range ratio r may be plus or minus, being -1 when the stresses are completely reversed.

If S_o is the endurance limit when the minimum strees is zero ($r = 0$) and S_{-1} is the endurance limit for completely reversed stresses ($r = -1$), it is evident from the Goodman diagram that the ratio of S_o to S_{-1} is 1.5. Experiments show that the ratio of S_{-1} to S_u varies somewhat, the average for ferrous metals being about 0.50, instead of 0.33 as shown by the Goodman diagram. For this reason Moore, Kommers, and Jasper (72) suggested a modification of the J. B. Johnson formula which does not depend upon an assumed ratio of S_{-1} to S_u, but which retains the value of 1.5 as the ratio of S_0 to S_{-1}. The formula is:

$$S_{max} = \frac{1.5S_{-1}}{1 - 0.5r} \quad \text{or} \quad S_{max} = \frac{3S_{-1}}{2 - r} \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Howell(4) suggested a "straight line" formula based on the test results obtained at the University of Illinois:

$$S_{max} = \frac{S_{-1}(r + 3)}{2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

In Fig. 14, Eqs. 2 and 3 have been plotted, and it is seen that the Howell formula agrees quite well for values of r ranging from -1.0 to 0. For this same range of r, Eq. 2 is slightly more conservative than Eq. 3, while for plus values of r the Howell formula is the more conservative.

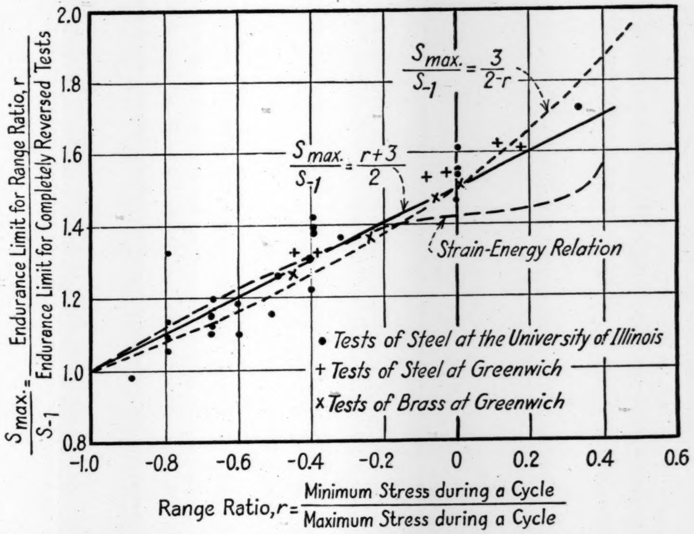

FIG. 14.—Diagrams for Modified Johnson-Goodman Formula, Howell Formula, and Strain-Energy Relation for Effect of Range of Stress.
Courtesy of the McGraw-Hill Book Co.

Strain-energy Hypothesis:

In 1919 Haigh(31) suggested that the strain energy absorbed within the elastic limit might be of more general application as a criterion of failure than the hypotheses of Saint Venant, Rankine or Guest. In 1923 Jasper (44) applied this method to the case of repeated stresses, and suggested that the limiting energy per unit volume per cycle of stress might be found to be the same for the cases of reversed stresses and those not reversed. For the case in which the maximum stress is of opposite sign to the minimum stress, he derived the formula:

$$S_{max} = \sqrt{\frac{2S_{-1}}{1 + r^2}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4)$$

For the case in which the maximum and minimum stresses are of the same sign, he derived the formula:

$$S_{max} = \sqrt{\frac{2S_{-1}}{1 - r^2}} \ldots\ldots\ldots\ldots (5)$$

In Fig. 14 the strain-energy relation has also been plotted. It is seen that the agreement with experimental results is quite good for values of r from -1.0 to -0.2. For plus values of r the strain-energy curve lies too low.

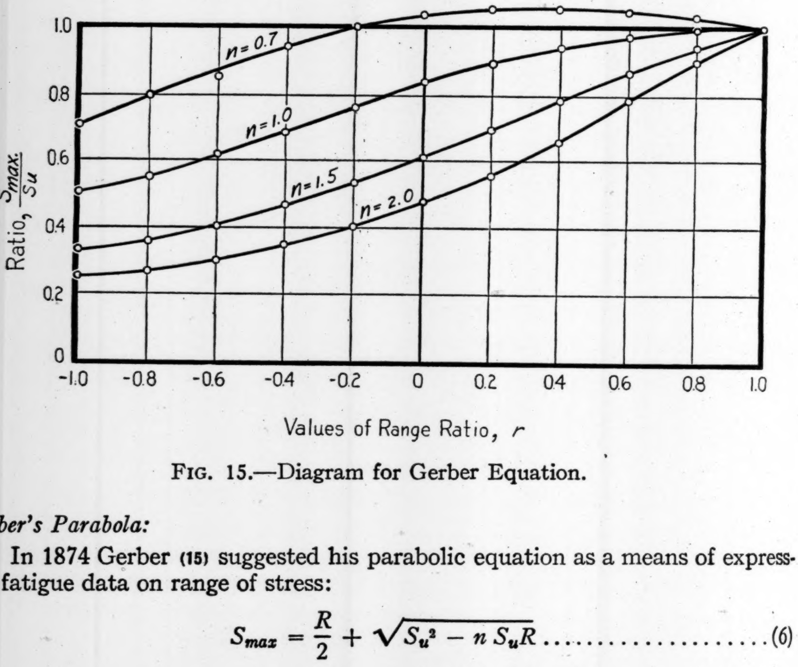

FIG. 15.—Diagram for Gerber Equation.

Gerber's Parabola:

In 1874 Gerber (15) suggested his parabolic equation as a means of expressing fatigue data on range of stress:

$$S_{max} = \frac{R}{2} + \sqrt{S_u^2 - n\,S_u R} \ldots\ldots\ldots\ldots (6)$$

where R = range of stress, in pounds per square inch, and

n = an experimental constant for any particular material.

It occurred to the author to arrange the equation in terms of range ratio instead of range of stress in order to determine whether this equation fits experimental results satisfactorily. Substituting $(S_{max} - S_{min})$ for R, the equation becomes:

$$\frac{1 + r}{2} = \sqrt{\left(\frac{S_u}{S_{max}}\right)^2 - n\,(1 - r)\,\frac{S_u}{S_{max}}} \ldots\ldots\ldots\ldots (7)$$

It can be shown that $n = \frac{0.5\,S_u}{S_{max}}$.

The present discussion will be limited to the values of range ratio from -1.0 to $+1.0$, which cover the more modern experiments. The ferrous metals and alloys give an average value of S_{-1} to S_u of about 0.5. When this is the case the value of n in the Gerber equation is 1. In Fig. 15 the Gerber value of S_{max} to S_u has been plotted for four values of n, covering the common ferrous and non-ferrous metals. The curve shows that when n equals 1 and r equals zero the ratio of S_o to S_u is 0.83.

In the following table are shown the ratios of S_{-1} to S_u, S_o to S_u, and S_o to S_{-1} taken from Fig. 12 and other results from *Bulletin 136*, Engineering Experiment Station, University of Illinois:

NUMBER	RATIO S_{-1} to S_u	RATIO S_o to S_u	RATIO S_o to S_{-1}
1	0.49	0.63	1.28
2	0.54	0.75	1.40
3	0.52	0.85	1.64
4	0.48	0.55	1.15
5	0.36	0.51	1.42
6	0.49	0.67	1.35
Average	0.48	0.66	1.37

This particular series of steels gives an average value of S_{-1} to S_u of 0.48. As shown above, the Gerber parabola requires that S_o to S_u shall be 0.83 when S_{-1} to S_u is 0.50, and n is 1. The table shows the experimental ratio to be 0.66. Evidently when r equals zero the Gerber equation gives values of maximum stress which are too high.

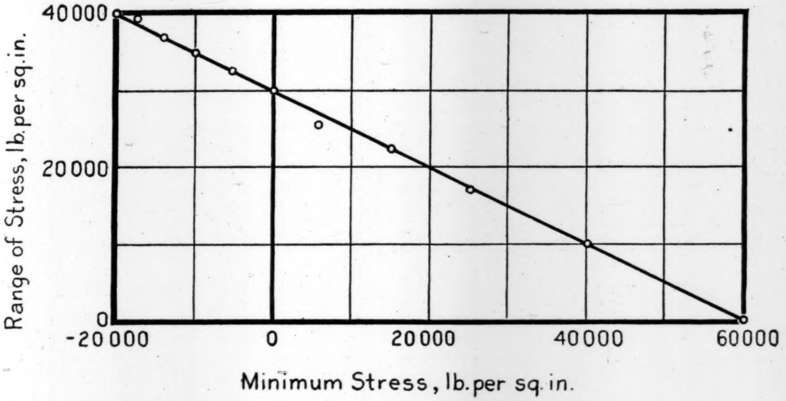

FIG. 16.—Diagram for Range of Stress.

It may be noted in passing that the table also shows that the value of 1.5 taken for the ratio of S_{-1} to S_o in Eq. 2 is probably too high, the average in the table being only 1.37.

In Fig. 13, which shows Haigh's results for brass, the ratio of S_{-1} to S_u is 0.42, and this would give a value of n for Gerber's equation of 1.19. This in turn would produce a value of S_o to S_u of 0.71 when r equals zero. The experimental result is 0.60, showing again that the Gerber values are too high and therefore not safe.

In his book on "Fatigue of Metals"(22), Gough has used the Gerber parabola by plotting range of stress as the ordinate and average stress or mean stress as the abscissa. However, if the fundamental equation does not express results correctly, the particular method used in plotting the equation will not recommend itself as a generally useful method.

Other Methods of Plotting:

Bairstow(2) has used a diagram in which range of stress is plotted as the ordinate and minimum stress as the abscissa. In Fig. 16 such a diagram has been plotted on the assumption that the values computed from Eq. 1 were correct, and that the steel had a tensile strength of 60,000 lb. per sq. in. If experimental results are found to agree with this diagram, it has the advantage of being a straight line relation which may be expressed by the following equation:

$$R = 0.5\,(S_u - S_{min}) \qquad \text{(8)}$$

Haigh(34) has used still another method of plotting fatigue results, in which alternating stress is used as the ordinate and steady stress as the abscissa. By steady stress is meant the algebraic sum of the maximum and minimum stress divided by two, also called the mean or average stress. The equation which Haigh has used in connection with this diagram is as follows:

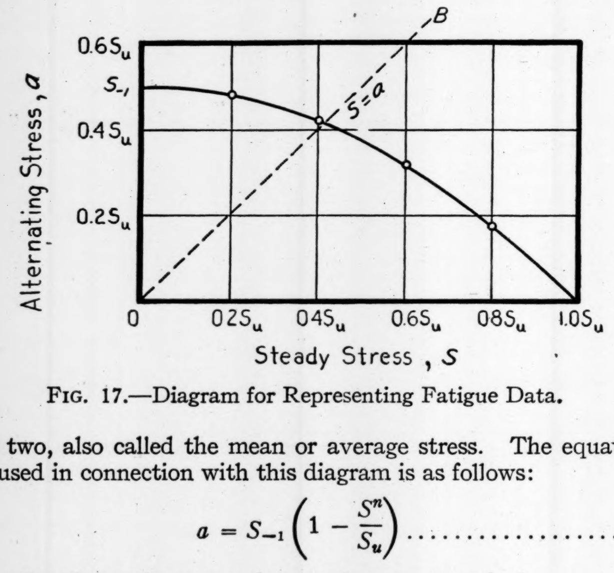

FIG. 17.—Diagram for Representing Fatigue Data.

$$a = S_{-1}\left(1 - \frac{S^n}{S_u}\right) \qquad \text{(9)}$$

where a = the alternating stress, in pounds per square inch,
S = the steady stress, in pounds per square inch,
n = an experimental constant,
S_u = the tensile strength, in pounds per square inch.

Haigh states that the constant n lies between the limits 1 and 2, varying with different metals.

In Eq. 9, when n equals 2, it can be shown that the equation is the same as Gerber's parabola. When n equals 1 it can be shown that the results would plot in a diagram similar to Goodman's.

Figure 17 shows the appearance of such a diagram when the exponent n equals 2, and S_1 is 0.5 S_u. For points on the diagram lying above the 45-deg. line OB the cycle of stress will be partly reversed, because for such a point a will be greater than S. A straight line connecting S_{-1} and 1.0 S_u would represent the results as given by the Goodman diagram.

As a picture explaining fatigue results on range of stress, the Goodman diagram is probably the most easily interpreted, and can be readily understood even by one not particularly familiar with fatigue data. In the opinion of the author the above diagram used by Haigh is, next to the Goodman diagram, probably the one which is most generally useful and easily interpreted. Also Eq. 9 has the advantage of being expressed in terms of S_{-1}, so that S_{-1} does not have to be some particular fraction of the tensile strength. In the exponent n the formula has a constant which should prove useful in adapting the formula to various kinds of metals.

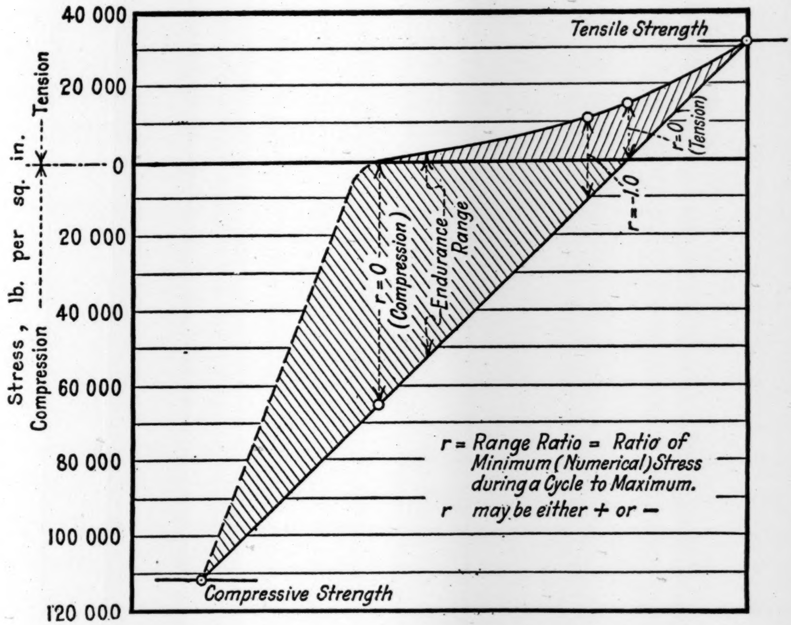

FIG. 18.—Diagram for Varying Endurance Limits of Cast Iron with Varying Range of Stress. (*Bulletin No. 164*, Engineering Experiment Station, University of Illinois.)

Diagrams Involving Number of Cycles:

The designer usually wishes to know the endurance limit for any given material. In some cases, however, it may be desirable to know the number of cycles which may be expected before rupture at stresses greater than the endurance limit. Moore and Kommers(74) have suggested a method of constructing such a diagram, which indicates roughly the probable number of cycles before rupture for various ranges of stress.

Range of Stress for Cast Iron:

Cast iron is similar to concrete in that its tensile strength is very much less than its compressive strength. This fact results in a diagram of range of stress which is somewhat different than might be expected for the ordinary wrought ferrous and non-ferrous metals.

Figure 18 shows the diagram for range of stress obtained by Moore, Lyon, and Inglis(77). These results were obtained on two machines, one of which subjected the specimen to axial stresses in compression, and the other subjected the specimen to cycles of reversed bending stress combined with a steady axial tension. The figure shows that when the unit stress was entirely compressive from zero to a maximum ($r = 0$), the endurance range was 65,000 lb. per sq. in., representing the endurance limit in compression. When a small amount of tension was introduced into the cycle the endurance range was at once reduced. For example, with 6400 lb. per sq. in. tensile stress in the cycle the endurance range was 38,400 lb. per sq. in. For completely reversed stress, that is, tensile stress equal to compressive stress ($r = -1$), the endurance range was reduced to 21,000 lb. per sq. in. Finally, when the unit stress was entirely tensile from zero to a maximum ($r = 0$), the endurance range was the least, being only 15,500 lb. per sq. in., corresponding to the endurance limit in tension.

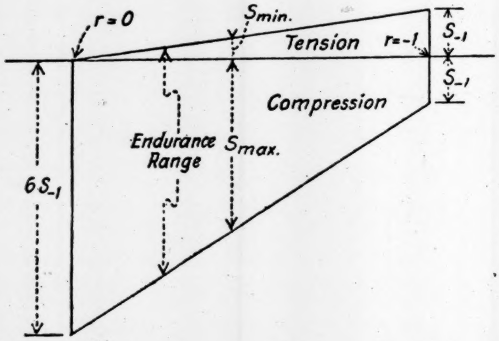

FIG. 19.—Portion of Diagram Shown in Fig. 18, from Maximum Compressive Endurance Range to Maximum Tensile Endurance Range. (*Proceedings*, Am. Soc. Testing Mats., Vol 29, Part II, p. 104 (1929)).

The endurance range, therefore, in these tests varied from 65,000 lb. per sq. in. when the stress was entirely compressive, to 15,500 lb. per sq. in. when the stress was entirely tensile. It is evident, therefore, that tensile stress in cast iron is especially effective in producing fatigue failure.

For that part of the diagram in which the unit tensile stress is numerically the greater, Moore, Lyon, and Inglis suggest Eq. 2, which has been previously given for wrought ferrous metals, thus:

$$\frac{S_{max}}{S_{-1}} = \frac{3}{2-r} \quad \ldots\ldots (10)$$

For that portion of the diagram in which the compressive unit stress is numerically the greater, Kommers (49) has suggested the following formula:

$$\frac{S_{max}}{S_{-1}} = \frac{6}{1-5r} \quad \ldots\ldots (11)$$

Equation 11 covers the part of the diagram shown in Fig. 18 which is the same as that portion of Fig. 19 in which the compressive unit stress is numerically the greater, except that the upper limit of tensile stress has been approximated by a straight line instead of a curved line.

Fatigue Strength Under Reversed Shearing Stress:

Test data for the fatigue strength of metals subjected to cycles of reversed torsion has been obtained(74) at the University of Illinois, the U. S. Navy Engineering Experiment Station, the British National Physical Laboratory. The ratio of endurance limit for reversed torsion to endurance limit for reversed flexure ranges from 0.44 to 0.71 averaging about 0.55.

Range of Stress in Torsion:

Moore and Jasper(70) made torsion tests on six different series of steels in various conditions of heat treatment to determine the diagram for range of stress. These steels included a 0.49-per-cent carbon, a 1.20-per-cent carbon, and a 3.5-per-cent nickel alloy steel.

The ratio of S_o to S_{-1} varied from 1.85 to 2, while according to the Goodman diagram it should be 1.5. It is desirable to translate these results in terms of range of stress. According to the Goodman diagram the range of stress, for the case in which the minimum stress is zero, should be 0.75 of the range for complete reversal. The above results show that the range of stress under these conditions was either the same as for completely reversed stress, or in the worst case was 0.93 of that range. This indicates, therefore, that the range of stress is much more nearly constant under torsion than under bending or axial stress.

Similar results have been obtained by McAdam(61) at the U. S. Naval Experiment Station at Annapolis. McAdam's tests were made on eight series of steels, including plain carbon steels and alloy steels. He found that in the worst case the range of stress varied by 10 per cent and averaged 5 per cent. Recent tests by Hankins(37) give similar results.

McAdam noted in his experiments with stress which was not reversed that there seemed to be a maximum stress beyond which the upper limit of stress could not be moved without a corresponding increase in the minimum stress, and therefore a decrease in range of stress. He found that this "endurance yield point" was in the neighborhood of the elastic limit and yield point. A similar phenomenon has been observed in axial tension tests, and indicates that the upper limit of any range of stress should not exceed the elastic limit of the material.

On the basis of constant range of stress in torsion, Moore and Kommers(74) suggested the following formula for determining various maximum stresses for different values of range ratio:

$$\frac{S_{max}}{S_{-1}} = \frac{2}{1-r} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (12)$$

Effect of Steady Torsion on the Range of Stress in Reversed Flexure:

Shafts transmitting power are frequently subjected to a combination of cycles of reversed flexure together with a constant twisting stress. Lea (51) made fatigue tests on specimens of three kinds of steel subjected to varying combinations of reversed flexure and steady torsion. The steels were a chromium-nickel steel, a 0.14-per-cent carbon steel, and a 0.32-per-cent carbon steel.

Lea found that so long as the shearing stress due to the study torsion was below a critical value, no marked effect on the endurance limit in flexure was noticeable. Above this limiting value the endurance limit was markedly lowered. His tests were not sufficient in number to determine definitely this limiting value of shearing stress, but it seemed to be nearly equal to the endurance limit for reversed flexure. For example, the 0.14-per-cent carbon steel had an endurance limit in reversed flexure, without shearing stress, of about 37,000 lb. per sq. in. When a steady shearing stress of 33,800 lb. per sq. in. was added to the flexural stress the endurance limit was about 39,200 lb. per sq. in., a slight increase. With an added steady shearing stress of 43,500 lb. per sq. in., the endurance limit in flexure was reduced to 32,500 lb. per sq. in. Ono(117) has obtained similar results.

Conclusions:

The above discussion on range of stress makes it quite clear that the number of experiments which have been performed to determine range of stress is very small compared with the number of tests which have been made in reversed bending. This is extremely unfortunate and results in the conclusion that at the present time our knowledge of range of stress is far from adequate. All the diagrams and equations discussed in this paper should be looked upon as tentative until such time as further information makes possible more definite conclusions.

While the present knowledge on range of stress is far from adequate, yet certain conclusions seem to be fairly well established. Diagrams involving tension and compression seem to indicate that the range of stress is not constant, but that as the maximum stress increases the range of stress decreases. Diagrams involving torsion stress seem to indicate, on the other hand, that the range of stress is practically constant.

Since under most conditions it is not desirable to have materials permanently deformed, it follows that the elastic limit of a material should not be exceeded even though a diagram on range of stress shows that the maximum unit stress might exceed the elastic limit.

FATIGUE OF METALS AS AFFECTED BY METALLOGRAPHIC FEATURES

BY H. S. RAWDON[1]

The response of a metal to "fatigue" stresses, that is, repeated cycles of stress, is essentially the same in nature as it is to a static stress. Slipping on certain crystal planes occurs within the body of individual grains of the metal specimen and the path of the fracture, if fracture does ultimately occur, is transcrystalline in its course. This is characteristic, at least, for normal conditions of temperature. Gough and Hanson(24) have shown that slip bands will result from cycles of stress whose magnitude is considerably less than the fatigue range. Furthermore, they were unable to detect any marked difference between those due to safe ranges of stress and those due to unsafe ranges. Evidently the presence of slip bands on the surface of a metal specimen under "fatigue" stresses is not necessarily to be interpreted as evidence of incipient failure. On account of the different orientation of the constituent grains of any polycrystalline metal, the slip bands are not continuous from one grain to the adjacent one. If adjacent grains differ decidedly in orientation there appears to be a "shielding effect" at the boundary(21), that is, the slip bands stop short of the grain boundary. On account of the general "strengthening effect of intercrystalline boundaries," it would be expected that the endurance limit of a specimen consisting of an aggregate of a large number of grains would be higher than that of a specimen of the same material composed of only a few relatively large grains or even only one. This has been found to be true by Gough(23). In general, however, for ordinary commercial materials, the increase in the endurance limit secured by grain refinement over that of corresponding material in a coarsely grained condition, is true only to the extent that the tensile strength of the material is also increased by the grain refinement.

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[1] Chief, Division of Metallurgy, U. S. Bureau of Standards, Washington, D. C.

Although slip bands do not originate at the grain boundaries normally, there is some evidence that in the case of twinned grains, the conditions at the boundary of the twinned layer are favorable for slip to occur.

It is generally recognized that the presence of inclusions, often grouped under the term "dirt," in the structure of a metal is not favorable toward high endurance values. The shape and extent of the inclusions, however, and, in particular, their location with respect to the form of the specimen, have a very important bearing on the effect of such inclusions on the behavior of the specimen under test. Inclusions located at or very near the surface of a specimen of the rotating beam or cantilever type have a very marked effect, whereas identical inclusions within the body of the specimen will have practically no effect so far as acting as centers for incipient failure. When a crack has once started, however, the deeply embedded inclusions serve as convenient "stations" whereby the rate at which the crack is propagated through the section of the piece is accelerated.(54) Inclusions with sharp angular projecting corners are considered to be much more objectionable than smooth rounded ones. Inclusions drawn into a long thread-like form lying parallel to the axis of the rotating specimen are far less serious in their effect than if they are located transversely to the axis of the bar. There is *very* little information available as to the relative effect of inclusions on the behavior of specimens which are uniformly stressed over their entire cross-section (axial loading) as compared with specimens of the type of the rotating beam.

A second metallographic constituent as in a binary alloy usually does not act in the same manner as inclusions of material which are "foreign" to the alloy system do. This is true regardless of the fact that the constituent may be very hard and brittle, as, for example, cementite in steel. Such constituents ordinarily are not of an angular shape with sharp corners. The nature of the "bond" between the constituents of an alloy system is undoubtedly different from that between foreign inclusions and the matrix in which they are embedded, and this may play an important part in the matter. In some cases, however, a structural constituent may be just as potent in lowering the fatigue-resistance of a material as any foreign inclusions are. A striking example of this is graphite in gray cast iron. The matrix in this case is essentially a steel. The presence of the relatively large flakes of the soft and mechanically weak graphite lowers the properties of the aggregate far below those of the steel matrix itself.

Conditions of unsoundness, porosity, voids, etc., may have a very pronounced effect on the results of endurance tests according to the degree of unsoundness and the location of such areas. Internal separations such as "shatter cracks" found within rail heads, locomotive tires and similar rolled steel products serve admirably as nuclei from which fatigue cracks progress, since these defects are usually located transversely to the direction of stress.

It is a well-established fact that a condition of internal stress in a material is favorable to low values in the endurance limit. Such a condition of internal stress is not reflected in the visible microstructure of the metal although it must be related to the ultimate structure of the material. No information based on experimental data is available, however.

Non-uniformity in structure may often be very detrimental with respect to the fatigue-resisting quality of a material, particularly if the non-uniformity consists in the segregation of inclusions or a hard brittle structural constituent. The crack once started in the structurally weak portion is propagated into the sounder portions as a result of the stress concentration effect. There is some evidence to indicate that this may also be so in the case of some metallic coatings, if the coating is of a hard brittle nature.

FRACTURE UNDER REPEATED STRESS

BY H. F. MOORE[1]

In all cases in which it has been possible to observe the progress of fatigue failure in a specimen or a machine part there has been noted a crack which spreads under repeated loading to final fracture. Sometimes several such cracks have been observed. The genesis of this spreading crack is not clear. It seems to be sub-microscopic in size at first. Probably many, if not all, materials as produced have many small fractured regions scattered through them, especially near the surface.(25 115, 116).

In many cases it seems that these cracks originate at surfaces of slip. Gough(23) has pictured a wrinkling of the sliding surface resulting in the opening up of cracks. Parker Haigh(33) pictures minute volumes of material just below the surface of a part as subjected to tension in three directions: (1) from the metal inside, (2) the metal outside, and (3) the surrounding metal. Under such "triple tension" the shearing stress would be zero if the three principal tensions were equal and would be lowered even if the tension stresses were unequal, and, with diminished shearing action, fracture might be expected to follow instead of slip.

While in many cases fatigue cracks seem to arise from slip, in certain materials, notably in duralumin and antimony, fatigue cracks have been observed before there was present any evidence of slip.(78, 23)

In general, the effect of any cracks or marked surface irregularities is disastrous owing to the stress-concentration set up. However, the formation of a crack may release localized over-stress and transfer it to a wider area of understressed material. It is conceivable, although not very probable, that the formation of a crack might actually improve the stress distribution in a machine part or a test specimen.

Under repeated stress it seems quite possible that two contradictory actions may take place at the ends of a crack:

1. The crack tends to spread, owing to the stress concentration at its end.
2. For cases of stress repeated, but not reversed, and possibly for some cases of reversed stress, the end of the crack tends to become blunter, more rounded, thus tending to diminish the stress concentration. The progress of a crack, perhaps the actual stopping of its spread before complete fracture,

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may be pictured as depending upon the resultant effect of these two contradictory actions(74).

In a rough way, the recognition of the fact that fatigue failure is a spreading *fracture* is an explanation of the fact that there seems to be a correlation between tensile strength and endurance limit. Tensile strength is a fracture under one load, fatigue failure is a fracture under many loads. It is not surprising that there should be some correlation between them.

MECHANICAL HYSTERESIS AND FATIGUE

BY J. B. KOMMERS[1]

When a member is loaded in tension and then in compression, the stress-deformation curve may form a loop, as shown by Bairstow.(2) This phenomenon is called mechanical hysteresis, from analogy with magnetic hysteresis.

Bairstow found that when the stresses were not completely reversed there was developed a "permanent extension," due to the repeated stresses, in addition to the width of the hysteresis loop, which width he called "cyclical permanent set."

Ewing(8) made tests on long metal wires of various kinds, loaded between two limits in tension below the elastic limit as determined by ordinary extensometer tests, and found evidences of hysteresis in all cases.

Hopkinson and Williams(39) made some elastic hysteresis experiments on an 0.18-per-cent carbon steel. They took temperature readings with thermocouples, and also measured the energy dissipated by elastic hysteresis under cyclical variation of stress at a speed of 7200 cycles per minute. The dissipation of energy increased about as the fourth power of the stress range. Some tests were also made at very low speeds.

F. E. Rowett(89) carried on similar experiments, but he determined the area of the complete hysteresis loop more exactly than did Hopkinson and Williams. The hysteresis was found to be practically the same regardless of the speed of testing, at least up to 4200 cycles per minute. He found that the results of Hopkinson and Williams, calculated on the basis of the hysteresis loop shape which he determined, were almost in exact agreement at high and low speeds.

Rowett's results indicated that the hysteresis for hard-drawn tubes of steel at all stress ranges was only about one-eighth of that for the same tube after annealing. The hysteresis loss for the annealed tube varied about as the cube of the stress range.

Guest and Lea(29) determined some torsion hysteresis loops on a 0.15-per-cent carbon steel. Loops were obtained at unit stresses as low as ±1500 lb. per sq. in. Since this stress must have been considerably below the endurance limit of the material, it is evident that hysteresis loops can occur at unit stresses which would not cause ultimate fracture in fatigue.

After overstrain it was found that rest and low temperature annealing reduced the width of the hysteresis loop. Guest and Lea say: "Since fatigue effects depend upon the gradual increase of the width of the hysteresis loop with repetition, it would appear that boiling and tempering at comparatively low temperatures remove initial strains, and thus considerably increase the resistance of the steel to repetition of stress." This is in accord with test results by McAdam for cold-drawn non-ferrous metals.

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[1] Professor of Mechanics, Engineering College, University of Wisconsin, Madison, Wis.

By their tests on Armco iron, copper, and mild steel, Gough and Hanson(24) established the following facts: (1) permanent set was detected after the application of unit stresses less than the proportional elastic limit as ordinarily determined, (2) strain hysteresis was present at all ranges of stress whether safe or unsafe, (3) slip-bands were produced in all metals under a variety of types of stressing at unit stresses *below the endurance limit*,[1] (4) no marked differences could be detected in the effects on the microstructure by safe or unsafe stresses prior to the cracking stage, (5) *the most careful observation failed to determine the critical stage at which fatigue cracks first formed*, but when once formed the cracks were propagated by stress concentration effects, a process probably entirely different from the first stages of the fatigue test.

The experiments led to the conclusion that strengthening or hardening was caused by plastic deformation due to alternating stresses, and that this hardening may be caused by unit stresses either less than, equal to, or greater than the endurance limit. The starting of a fatigue crack was ascribed to the capacity of the material for cold working being exceeded at various localized sports throughout the specimen.

B. P. Haigh(32) has made tests on hundreds of specimens in which the rise of temperature due to mechanical hysteresis was recorded by thermocouples. He divides the hysteresis effects into three stages: primary, secondary, and tertiary.

The primary stage is present when the applied stress in the fatigue test is greater than the elastic limit or yield point. This stage would therefore be present in those materials, like open-hearth iron, in which the endurance limit exceeds the yield point. The primary stage is observed in the beginning of the test, is associated with the "heat bursts" which have been observed by other investigators, and seldom continues for more than 250,000 cycles when the applied stress is constant. This effect is a temporary one and does not afford reliable information as to what the endurance limit may be. For this reason Haigh is sceptical as to the value of short-time tests for determining the endurance limit by means of short runs under increasing increments of stress.

The secondary stage of hysteresis in a fatigue test is the most characteristic action, and continues during the greater part of the test. It is characterized by the relatively slow rate of variation in hysteresis, which may rise or fall slowly or may remain practically constant under constant stress.

The primary stage is brief and involves plastic flow and accompanying hardening of the metal. It is evidently a period of adjustment to the applied stress. The secondary stage, which involves great quantities of work and heat, seems to be associated with "elastic hysteresis," and does not involve changes in hardness such as result from the primary stage. When tensile and Brinell tests are carried out on identical specimens at the beginning and near the end of the secondary stage, there do not appear to be any perceptible changes in hardness. Numerous slip bands are formed during the primary stage, but if these are removed, it is found that few if any form during the secondary stage. The few that may be formed do not offer a sufficient explanation of the large quantities of work absorbed during this stage.

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[1] Gough's work on single crystals showed that the first slip tends to occur along atomic planes of weakness, as shown by the space lattice pattern.

The tertiary stage is observed at the end of the fatigue test, and is characterized by increasing hysteresis, which rises slowly at first and then more rapidly until the specimen breaks. This action is usually brief, but may continue for several million cycles. This stage is associated with the plastic flow accompanying the gradual opening of the fatigue crack, which is often visible during the latter part of the tertiary stage but never during the secondary.

In general, for stresses that eventually cause failure by fatigue, the elastic hysteresis during the secondary stage continues to rise. It is only seldom that a specimen does not fail if elastic hysteresis has continued to rise during a considerable period. In some cases, however, hysteresis has increased for several million cycles, attained a maximum, and then slowly decreased for many millions of cycles without fracture. On the other hand, in a certain ductile brass, hysteresis decreased during five million cycles, and yet the specimen finally fractured. However, even in this case, the hysteresis increased during the final stages of the test.

Specimens in the secondary stage of the fatigue test were tested under low and increasing ranges of stress to determine how the hysteresis increased with the range. The hysteresis increases with no constant power of the range, but the power increases with the range. Haigh is of the opinion that elastic hysteresis cannot be regarded as a direct measure of the rate at which fatigue is being effected in the metal.

The action shown by the changes of elastic hysteresis seem to be the same whether final failure takes place in an inter- or intra-crystalline manner. Whatever happens at the crystal boundaries in the one case, or on planes within the crystal in the other, is inferred to be very similar.

The phenomenon of mechanical hysteresis seems to be associated with plastic action. Fatigue cracks may be caused by repeated stress causing plastic action, but plastic action does not always cause fatigue. Whether fatigue cracks can be started without any previous development of hysteresis is as yet a matter of uncertainty(**78**).

DETECTION OF INCIPIENT FATIGUE FAILURES

BY R. L. TEMPLIN[1]

For many reasons it would be highly desirable to be able to detect fatigue cracks in metals or structures before actual failure of the part of structure occurs. The methods or procedure necessary in detecting signs of incipient fatigue failures must of necessity vary considerably not only with the material and structure but also with the conditions of service and the frequency of inspections accorded the structure. With this in mind many suggestions have been made relative to methods for use in detecting fatigue cracks in their early stages.

A periodic inspection method frequently used in some railroad shops to detect incipient failure is the oil-whiting test. In locating sub-microscopic cracks by this method, the surface of a part to be examined is first painted with a film of oil and lampblack which is allowed to soak in and is then wiped off. The surface is then covered with a wash of whiting and alcohol. After this coating is dry, the part is struck with a hammer and if the oil and lampblack have penetrated any cracks, they will be forced out and leave a black mark on the white coating.

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[1] Chief Engineer of Tests, Aluminum Co. of America, New Kensington, Pa.

Some use has been made of high-power and low-power microscopes but the method is not very practical for general shop examinations. A low-power microscope along with the oil-whiting test was used quite successfully in an investigation reported in detail by H. F. Moore(67). Briefly, the conclusions arrived at from this work concerning detection of incipient fatigue failure were as follows:

> 1. Fatigue cracks could be detected in specimens cut from car axles and subjected to stresses slightly above the endurance limit, before one-half the life had passed. The higher the stress, the fewer were the cycles between detection of a crack and final failure.
> 2. The chances of detecting a fatigue crack before failure is expected are better for full-size axles than for small fatigue test specimens.
> 3. In conjunction with service records, a periodical shop inspection by means of the oil-whiting test may be expected to have a good degree of effectiveness in detecting incipient fatigue cracks in car axles in service before failure is imminent.

A method of detecting cracks applied by the American Steel Foundries is to subject a casting to repeated stress in a special testing machine. When a crack is expected, the surface is sprayed with gasoline. With further repetition of stress, the gasoline penetrates a small crack and forms a line of bubbles which marks its location.

Another method which has been found useful in detecting very small cracks in iron and steel plates is that developed by Rawdon and his associates at the Bureau of Standards(87). In this method the piece to be examined is polished, magnetized, and covered with a wash of kerosene in which is suspended "iron mud" from lapping disks. Cracks are then located by the gathering of the "iron mud" particles along the cracks.

A number of investigators have done considerable work on various methods of non-destructive inspection, based on the action of a direct or alternating magnetic flux passed through a specimen. The magnetic tests have given some promise for certain machine parts of ferrous metals.

R. L. Sanford(90) of the Bureau of Standards was unsuccessful in attempts to detect internal fissures in steel rails by magnetic means. The success of a magnetic method described by Suzuki(100) of the Japanese Government Railways has not been substantiated. Fischer(10) found that magnetic changes, noted in specimens of steel after having received varying cycles of reversed bending stress, showed no indication of incipient fatigue failure. The magnetic effects resulting from redistribution of internal stresses are so large as to mask the magnetic changes that would result from the formation of a small crack.

The general principle of the electrical resistance method has been used with marked success by Sperry(94) to detect incipient fissures in steel rails. Although this method seems to be fairly well established, some difficulty in the interpretation of results has been experienced in common with the magnetic method. Applied to axles that have been in service, the Sperry method of inspection has located and made a permanent record of fatigue failures in the early stage, while they were still too small to be located by the oil-whiting test, but it is not yet possible to detect minute fissures which will sometimes develop into fatigue failures.

H. F. Moore(75) in summarizing the difficulties in detecting fatigue cracks by means of the various short-time tests, with the possible exception of the power-input test and the electrical resistance test, says that the difficulty "seems to be that they detect slip rather than the starting of a fatigue crack."

Chemical analysis, coarse etching, complete physical tests, metallographic examination, and X-ray radiographic inspection have been used by Sisco(92) in detecting incipient failures of aircraft parts. A successful method of etching surfaces of aluminum alloy aircraft propeller blades that have been in service and inspecting for fatigue cracks with a low-power microscope has been described by Lyon(55).

Although every type of incipient failure cannot be detected by the most rigid inspection, a systematic inspection of machine parts of structures subjected to repeated stresses will often warn of impending fatigue failures. In some instances fatigue cracks have been detected in steam turbine disks before they had spread to failure. The failure of cables is another example where warning of approaching fatigue failure is often given by the breaking of individual strands of the outer layers.

EFFECT OF ALLOYING AND HEAT TREATMENT ON THE ENDURANCE LIMIT OF STEEL

BY H. W. GILLETT[1]

The endurance limit of sound, clean, wrought steel is roughly half the static tensile strength for all steels ranging from pure iron up to those heat treated to a Brinell hardness of about 400, irrespective of structure(74, 22). They may contain ferrite only, ferrite and pearlite, troostite, sorbite, considerable martensite or be partly or wholly austenitic, without materially altering the endurance ratio. Neither is grain size of any particular effect.

Any marked drop in the endurance ratio is due more to dirtiness of the steel or to the presence of other internal defects than to structure or composition.(18) Any marked increase in the ratio is more probably due to cleanliness of the steel above the commercial norm or to exceptional absence of internal stress, than to the presence of any particular alloying element or of any particular metallographic structure resulting from heat treatment.

When the Brinell hardness of the steel rises much above 400, as in steels of "spring temper," the endurance ratio tends to be less than 0.50(52), but may often be brought close to it by a prolonged draw which will remove internal stress.

Broadly speaking, it makes no difference in the endurance limit, when viewed from the basis of comparison with the static tensile strength, by what alloying agents or heat treatment that strength has been obtained. Small apparent deviations from this relationship met in individual comparisons are of so low an order of magnitude and so discordant in comparisons by different observers that no fine-haired generalization can be drawn. Despite some individual opinions to the contrary, there is no acceptable evidence that a high static elastic ratio or high ductility, such as may be obtained by suitable alloying and heat treatment, at all improves the endurance ratio. In an endurance test of a small specimen, a strong, brittle steel acts just like an equally strong, ductile steel.

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[1] Director, Battelle Memorial Inst., Columbus, Ohio.

All the above refers to a standard endurance test in completely reversed bending, with the specimen properly polished and free from stress concentration due to poor fillets, nicks or notches. That does not mean that there is not a vast difference in different alloy steels or in steels differently heat treated as regards their ability to withstand actual service under commercial, not test, conditions. A steel part in service may be called upon to withstand a few application of overstress without material damage that will later cause early failure under service stresses.(67) Steels vary in their ability to stand overstress without material damage. Here ductility and toughness are desirable. Steels vary in their ability to be strengthened by understressing. There is some, though none too clear, indication that ductility aids in ability to be thus strengthened(50).[1]

If the steel is not to be used under completely reversed stress but instead has to withstand an unbalanced stress range, say from slight compression to high tension, the upper limit of the allowable stress range is fixed by the yield point of the steel. In such service a steel of high elastic ratio, such as may be obtained by suitable alloying and heat treatment, is highly desirable. Even here there is no choice among the alloying elements so long as the static elastic ratio of the alloy steels is the same. If a machine part is to be used in axial loading so that the properties of the whole cross-section are crucial and not those of the surface only, then the uniformity of static properties through the whole cross-section is important, and a heat-treated alloy steel that has good depth-hardening properties is superior to one that has not.

In corrosion-fatigue the composition and heat treatment of the steel are most important, not because of any difference in static properties, but because of differences in corrosion resistance. In steels that are not corrosion resistant, high static properties gained by alloying and heat treatment have very little effect on the endurance limit under corrosion simultaneous with repeated stress. The strongest corrodible heat-treated alloy steels are little if any better than the weakest carbon steel(62).

Steels vary greatly in their susceptibility to the effect of surface notches. In a laboratory test on a polished bar this variable is eliminated. In practice it is not. In general, hard steels, however their hardness is obtained, are more susceptible to the "notch effect" than are softer or tougher steels. If a part, like a spring, is to be used with a rough, notched surface, the service endurance limit will fall astonishingly from the laboratory endurance limit on a notchless specimen. The rate of propagation of a surface notch becomes significant in practical service. For springs, for example, one eye should be kept on the laboratory endurance limit and the other on the notched-bar impact value or some similar measure of toughness.

The propensity toward open or incipient (concealed) quenching cracks, and that toward the formation of a decarburized surface in heat treatment, also vary with different compositions and heat treatments, and these have a vast effect on the service endurance limit.

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[1] NOTE BY J. B. KOMMERS.—Tests on cast iron and Armco iron indicate that the less homogeneous metal may be strengthened due to understressing by a greater percentage than the more homogeneous metal.

One of the most illuminating investigations comparing laboratory endurance limits and service of steel when handicapped by surface roughness, surface decarbonization or internal quenching cracks or strains is that of Hankins(35) and co-workers.

In order to get reproducible and dependable laboratory endurance tests, it is necessary to eliminate all sources of stress concentration. When this is done, the choice of alloying elements and the heat treatment have no effect so long as the static tensile strength is the same so that the results of these variables, in laboratory tests, resemble the snakes of Ireland.[1]

In practice, unless all notches and stress raisers are avoided, the effects of alloying and heat treatment are very great. A soft steel may out-strip a hard one in service, and for equal hardness the tougher and more ductile the steel and the higher its notch-toughness, the better.

An outstanding conclusion from experimental data is that the fatigue strength of steel may be greatly increased by suitable heat treatment, especially in the case of high-carbon steels and alloy steels, for which the percentage of increase may be as high as 200 per cent.

OVERSTRESSING IN FATIGUE

By T. McL. Jasper[2]

In defining what is considered under the heading of overstressing in fatigue the question is considered to bear only where repeated stresses are applied in the functioning of a structure in service. Cold rolling, cold forming, although all being performed by stressing the part or structure above the yield point of the materials, are not considered in this section under the head of overstressing.

Overstressing under the above heading, therefore, can be considered as the degree of stressing under service conditions which results in permanent injury to a structure. When applied to fatigue, therefore, it introduces the question as to what is the degree of stress (measured in terms of tensile strength, endurance limit, or some other limit) which will result in impairing the structure under repeated stress.

Under repeated stress it is found that if we try to impose many millions of stress applications at values above the endurance limit the effect is failure. If, however, a *few* repetitions of stress are applied above the endurance limit, as might occasionally occur in a service structure, it is found that the endurance limit of the structure is not very materially affected. This, of course, depends on the relative value of the occasional stress application and on the number of applications of such overstresses.

In machine design there is no intention of using working stresses above the endurance limits, but inability to properly analyze the stress condition often results in higher stresses than that calculated and incidentally results in overstressing. If the problem involved is one of *many* repetitions of this overstress then the result will eventually be failure of the part. However, if in the life of a structure an occasional overload occurs, due to occasional carelessness in operation or to an occasional unforeseen circumstance, such overstressing will not in general materially affect the life of the structure. The effect of occasional overstress depends on the kind of material used as to whether it is brittle or ductile and on the degree of the overstress.

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[1] Note by J. B. Kommers.—It must be kept in mind that the magnitude of internal stress produced by any heat treatment is of importance in this connection.

[2] Director of Research, A. O. Smith Corp., Milwaukee, Wis.

The measured endurance limit is rarely above the static yield point of the material considered. In many steels and other materials the endurance limit is considerably below the static yield point. It may be stated that occasional overstress within the yield point of a tough, ductile material has very little effect on the life of a structure in service. It should be noted that only ductile materials have yield points.

For consideration of brittle materials, therefore, an appropriate elastic limit must be defined in order to apply under the above statement. For all practical purposes an elastic limit which is that point in the stress-strain diagram which has a slope with the stress axis one and one-half times that of the slope of the initial portion may be defined as the elastic limit to be used. This is usually called Johnson's elastic limit.[1]

Occasional overstressing above the yield point or elastic limit has increasingly detrimental effects on the life of a structure. This is more pronounced in brittle than in ductile materials and for this reason brittle materials are not capable of taking care of points of stress intensification as adequately as ductile materials.

COLD WORKING

BY T. MCL. JASPER[2]

In discussing the question of cold working in connection with fatigue it is necessary to define what is meant by cold working. Cold working, such as cold rolling or wire drawing, is not usually performed with the metal at room temperature. The metal becomes quite hot as it is rolled or drawn or pressed, but its temperature does not reach the critical temperature necessary for recrystallization. Coining is usually performed on ductile materials cold. The effect of these operations is to increase the fatigue strength of steel and most other metals.

It might be stated briefly that such cold working which affects the ultimate strength of metal also affects the fatigue strength in a similar manner, that is, if cold working increases the ultimate strength of steel then it also increases the fatigue limit as well, and in about the same proportion(74).

However, violent cold working tends to start fracture in the internal structure and sometimes on the outside surface of metals and when such is performed the fatigue strength is decreased. The degree of cold working therefore must be considered in this connection if an adequate appreciation of its effect is to be obtained.

It is believed that each metal and each combination of composition in a general type of metal has an optimum degree of cold work above which no increase of fatigue strength is obtained and below which strengthening in varying degree is obtainable.[1]

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[1] NOTE by H. F. MOORE.—As noted by Mr. Jasper in a previous paragraph, the injury done by occasional overstress varies for different metals. For a tempered spring steel the endurance limit will probably be well below the elastic limit, and occasional stresses above the endurance limit may do damage by starting a fatigue crack, even though this stress is below the elastic limit.

[2] Director of Research, A. O. Smith Corp., Milwaukee, Wis.

In the zone of benefit from cold working it has been found that the degree of cold working for maximum benefit is neither found by making the largest practical number of passes in the cold working operations nor the smallest number, and for this reason the rate of reduction in cold-rolling and cold-drawing operations can be very properly studied in order to perform cold-working operations for maximum practical improvement of fatigue and static strength.

The question of cold working which more nearly comes under the heading of overstressing is discussed under this heading. Cold working by repeated stressing is effective in increasing the endurance limits in some metals but not in others. In general metals have their endurance limits increased by repeated stressing provided the stressing is performed at or below the endurance limit, but this proportionate strengthening varies widely for different metals.

Cold forming of materials in general very materially increases their ultimate and fatigue strengths. However, again, the degree of forming which is performed has a considerable bearing on the ultimate results obtained in a manner similar to that described under paragraphs on cold rolling and wire drawing. Certain brittle materials of course cannot be cold formed without fracture.

STRENGTHENING BY UNDERSTRESSING

By H. W. Gillett[2]

If a set of specimens of a metal or alloy is subjected to repeated stress, each specimen being subjected to one stress only until it either breaks or remains unbroken for many millions of stress cycles, and if the stress-cycle diagram becomes parallel to the cycle axis, an endurance limit has been found for that material in its original condition.

As has been discussed in the section on overstressing, if a specimen is tested at a stress above the endurance limit, so that it would finally fail at that stress, but the test is interrupted after the run has continued for, say, a third of the expected life of the specimen, there may be no visible damage, but damage there is just the same.

If the specimen is retested at a higher stress, it will fail earlier than a virgin specimen would at this higher stress.(67) The specimen has been damaged by overstressing. This is just what one would expect, knowing that "fatigue" failure is a progressive fracture.

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[1] Note by R. L. Templin.—It is quite the customary procedure to perform such operations as rolling and drawing on the non-ferrous metals, exclusive of perhaps monel metal and nickel, at room temperatures. We ordinarily think of such temperatures as coming within the category of the term of "cold." The effect of such cold working is distinctly to increase the fatigue strength of the materials. The amount of this increase varies within wide limits depending on the material. In the case of pure aluminum, for example, the endurance limit may be increased as much as 60 per cent by cold working, whereas in the case of duralumin cold worked after heat treatment, the increase in endurance limit is much less. There doubtless are specific cases in which "each metal and each combination of composition in a general type of metal has an optimum degree of cold work above which no increase of fatigue strength is obtained and below which strengthening in varying degree is obtainable," but as a general statement, this is rather sweeping.

[2] Director, Battelle Memorial Inst., Columbus, Ohio.

If, on the other hand, a specimen is first tested under a repeated stress at or slightly below the endurance limit (for example, one of the unbroken specimens that has run many million cycles unbroken in the original set of tests to determine the endurance limit), and is then subjected to a higher repeated stress, say one at which a virgin bar would fail in a few hundred thousand cycles, an astonishing result is obtained. The specimen will endure many million cycles. It has been definitely strengthened by understressing.(70, 77, 50)

If the first increase of stress is not too great, and the specimen is allowed to run many millions of cycles at a stress not greatly exceeding the virgin endurance limit, the strengthening may progress still further so that on a third test at a still higher stress, it will last longer than if it had been immediately raised to the third stress. The process of "coaxing" or "teasing" can be continued, and a set of specimens produced which, if they were tested without knowledge of their previous history, would lead the observer to believe that the endurance limit of the material was higher, perhaps by as much as 25 per cent than that found by tests on virgin material.

On a rotating-beam specimen, the surface only is stressed to the calculated fiber stress, and the interior is not so highly stressed. the axis in fact having zero stress. Even though the surface only can be very much affected by understressing, the hardness and tensile strength of the specimen are slightly but detectably increased and the ductility decreased. The microstructure does not appear to be altered(78).

If the repeated or reversed loading is axial so that the whole cross-section is stressed to the nominal fiber stress the effect of understressing on the static properties is more readily observable, a 20 per cent increase of tensile strength being sometimes found.

The phenomenon of strengthening by understressing has every evidence of the effect of cold working except that no appreciable change of dimensions of the specimen occurs. If it is cold working, it must be cold working on an extremely minute, submicroscopic scale.

It has sometimes been thought that only those materials which could be satisfactorily strengthened by ordinary cold working, involving great permanent deformation, were susceptible to strengthening by understressing, but that idea does not hold since it may be very marked in hard heat-treated steels of Brinell hardness of say 500, and in cast iron, and not very marked in a ductile brass. Freeman, Dowdell and Berry(13) obtained marked strengthening by understressing on rail steel.

Different materials vary in their ability to be strengthened by understressing, and at present we cannot predict without trial whether a given alloy will respond greatly or slightly to understressing.

It appears that the effect of understressing is more marked the higher the stress and the greater the number of cycles[1] but no general quantitative relationship can be stated so far(50).

It appears that there are two opposing tendencies when a metal is subjected to repeated stress, one a tendency to start a crack, the other a tendency to strengthen the metal by what we may think of as a type of cold working on a very minute scale. At high stresses the damaging effect predominates and failure ensues. At low stresses, the strengthening effect predominates. At the endurance limit, the two tendencies balance, on a virgin specimen.

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[1] NOTE BY J. B. KOMMERS.—This increase of endurance limit with number of cycles applied does not go on indefinitely. In tests of cast iron no increase was observed above 15,000,000 cycles.

If the specimen is understressed so that the beneficial effect has time to be exerted, the balance thereafter occurs at a higher stress. It is as if the unfavorably oriented portions of the structure were so improved that they became strong enough to stop the advance of an incipient, sub-microscopic crack. Indeed, an overstressed specimen which has not been run so long that the incipient cracks have developed too far can be more or less "cured" by understressing which fact agrees with the conception that in a virgin bar the two tendencies oppose each other.

There are no data to indicate whether a specimen that has been strengthened by understressing in a reversed axial tension-compression test is equally strengthened against a different type of stress, torsion, for example. That is, we do not know whether a part machined from an understressed axial-loading test bar would be better able to withstand service stress than a virgin bar. The improvement may be specific against stresses applied as they have been in past stressing, but not for other stresses. An old automobile axle which has been understressed and not overstressed in service is a better axle than a new one, but we do not know that a connecting rod made from the old axle would be better than one made from an unused axle. It is obvious that gradual "breaking-in" of a part in service by starting with light loads will favor strengthening by understressing.

The most obvious application of the phenomenon of strengthing by understressing is in the endurance test itself. If one tries to save specimens by running the same specimen at a low stress and increasing the stress till it breaks, the specimen is strengthened by understressing, does not represent the virgin material, and gives an erroneously optimistic idea of the endurance limit. Such a method of testing must be condemned.

On the other hand, if we start at high stresses and break bars, establishing the *S-N* curve for virgin material, and finally, by testing bars at progressively lower stresses, find the endurance limit, we may stop the test at say five million cycles unbroken for steel or a correspondingly greater number of cycles for non-ferrous alloys, and then raise the stress to that corresponding to a life of say one-fourth million cycles for a virgin bar.

If the bar thus re-tested runs for decidedly more cycles than the one-fourth million, probably a million or so, because of strengthening by understressing, we are assured that, had it been allowed to run longer at the original stress, it would have continued to run unbroken. Thus a total of say 5 plus 2 or 7 million cycles becomes about as convincing as one of 25 million at the lower stress only.

If, on the other hand, the material is one which like duralumin or monel metal may not show a truly horizontal *S-N* curve after a thousand million cycles a specimen retested at a higher stress will probably fall below the virgin *S-N* curve and thus indicate that the test at the original stress was really one at an overstress, and that damage was starting, instead of being at an understress and strengthening the material.

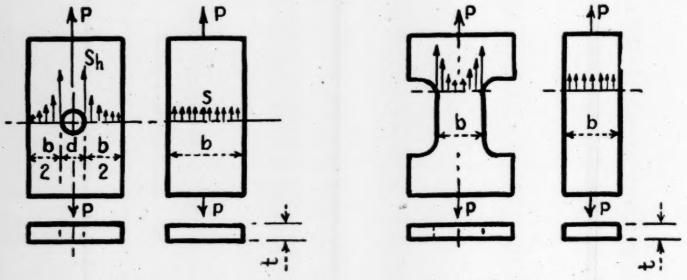
Johnson and Oberg(46) have used this method of attack in the study of duralumin and in runs at stresses that will give over half a billion cycles unbroken, find, on restressing at a higher stress, evidence of damage, and thus proof that the initial stress, though allowing a very long life, was actually above the endurance limit for infinite life.

STRESS CONCENTRATION AND FATIGUE STRENGTH

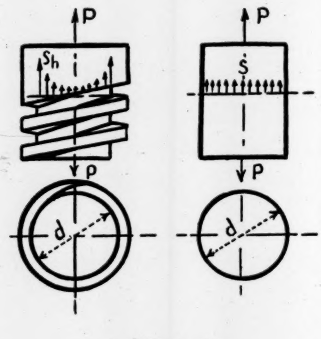
BY R. E. PETERSON[1]

Introduction:

It is quite generally known that abrupt changes in cross-section, such as caused by fillets, holes, grooves, etc., introduce localized stresses of relatively high magnitude. The ratio of the maximum stress occurring at a change in cross-section to the computed uniform stress is defined as the stress concentration factor k. Thus in Figs. 20 (a) and (b), $k = S_h bt/P$ and in Fig. 20 (c), $k = S_h \pi d^2/4P$. For bending, the maximum stress obtained is compared with the maximum stress assuming linear stress distribution (flexure formula). Thus in Figs. 20 (a) and (b), $k' = S'_h bt^2/6M$ and in Fig. 20 (c), $k' = S'_h \pi d^3/32M$.



(a) Hole (b) Fillet



(c) Threads

FIG. 20.—Examples of Stress Concentration.

In a few cases, stress-concentration factors have been determined mathematically, making use of the assumptions of the theory of elasticity, that is, Hooke's Law and homogeneous, isotropic material. A number of photo-elastic investigations have also been made on problems involving stress concentration, the results in general being in good agreement with analytical solutions. Assuming that the theoretical stress-concentration factor is available, there still remains the important question of the significance of this factor with respect to failure in engineering materials(**74, 22, 111, 26**).

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[1] Research Engineer, Research Dept., Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.

If a specimen of ductile material having an abrupt change of section is subjected to a steady load, such as in a tension testing machine, there will not be a weakening effect due to stress concentration(**98, 3, 57, 104, 82**). Because of ductility, the highly stressed portion yields slightly with a resulting redistribution of stress and ability to carry additional load. A slight increase in strength is obtained due to absence of lateral contraction(**104, 70**). If a similar specimen of brittle material is subjected to a steady load, the highly stressed portion does not yield as in the case of a ductile material. Redistribution of stress does not occur and consequently a reduction of strength is obtained. The stress-concentration factor for brittle materials subjected to steady load is less than the corresponding factors obtained mathematically or photo-elastically(**1, 84**).

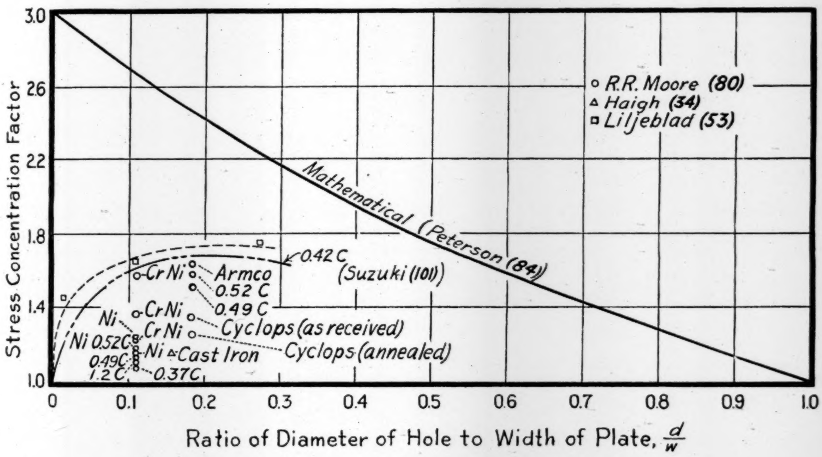

FIG. 21.—Stress-Concentration Factors for Holes.

If a specimen having an abrupt change of section is subjected to fatigue loading, a reduction of strength is obtained due to stress concentration, whether the material is ductile or not.[1] The stress-concentration factors as obtained by fatigue tests are in all cases lower than the corresponding factors obtained mathematically. Data on fatigue stress-concentration factors for holes, fillets, and notches are summarized in the following sections and wherever possible comparisons are made with theoretical values.

Holes:

The stress concentration due to a circular hole in a plate of infinite width has been solved mathematically(**47, 12**). Experimental confirmation has been obtained by the use of India rubber models(**99**). Some data have also been obtained photo-elastically(**5**). The mathematical stress concentration factors are: $k = 2$ for equal uniform tensions in two directions at right angles to each other, $k = 3$ for uniform tension in one direction, $k = 4$ for uniform tension in one direction and uniform compression of same numerical magnitude at right angles to direction of tension. This latter case corresponds to torsion in a thin tube. The case of two or more holes has also been solved (110) and also the case of a reinforced hole(103). As the width of the plate approaches the size of the hole, the stress concentration factor decreases(84). For an elliptical hole, which in the limiting condition can be made to simulate a crack, a solution is also available(41). The stress concentration factor for an elliptical hole subjected to uniform tension perpendicular to the major axis is $k = 1 + 2a/b$, where a is the major axis and b is the minor axis.

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[1] NOTE BY J. B. KOMMERS.—In such very non-homogeneous metals as cast iron the weakening by stress-concentration due to holes, notches, etc., may be negligible.

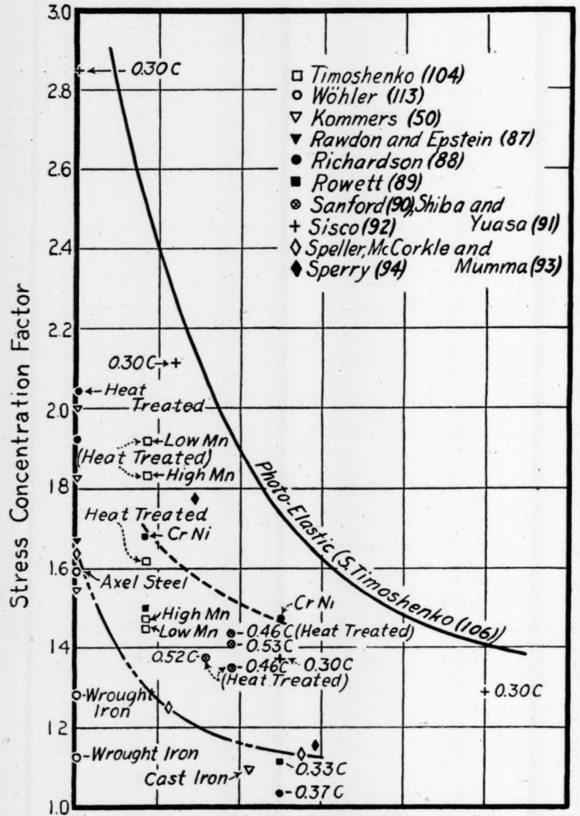

FIG. 22.—Stress-Concentration Factors for Fillets.

Fatigue tests of the effect of holes have been made by only a few investigators(71, 77). Stress-concentration factors due to holes are shown in Fig. 21. It will be noticed that values for such factors obtained from fatigue tests are considerably lower than theoretical values and in no case is a value of $k = 3$ approached. There seems to be some evidence that for very small holes the weakening effect is decreased and approaches zero(84, 53, 101). Small slag inclusions and unsoundness result in a condition akin to the presence of small holes. "Dirty" steels have been studied from a fatigue standpoint(18, 70), the general conclusions being that the inclusions act as "stress raisers" so that a reduction of endurance limit is obtained with considerable "scatter" of test data.

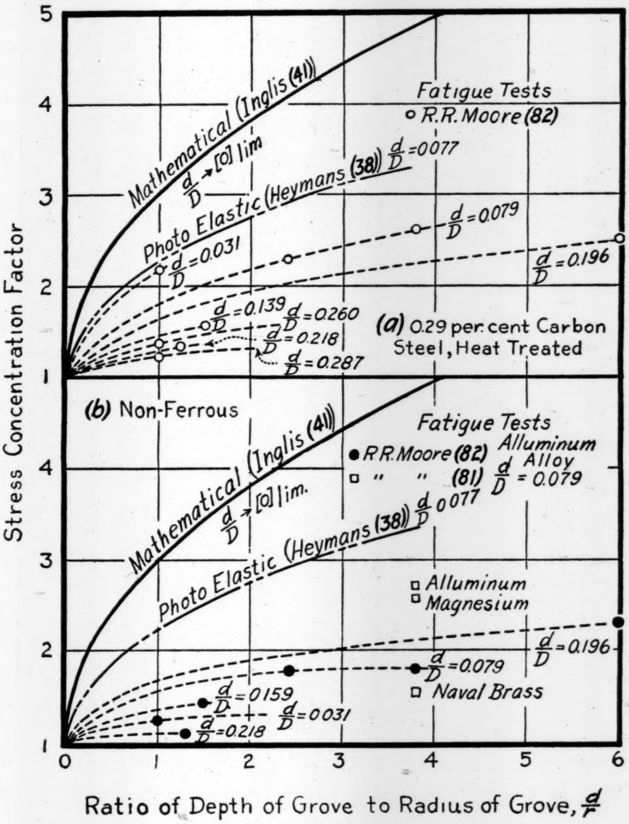

FIG. 23.—Stress-Concentration Factors for Notches.

Fillets:

The fillet problem has been studied in some detail photo-elastically(106). This work has been extended to cover gear tooth fillets,(105) good agreement being obtained with the general photo-elastic investigation of fillets. It is interesting to note that Wöhler, whose work in fatigue of metals (1852–1869) was essentially pioneer, made tests on the effect of a sharp corner(113), obtaining values corresponding to $k = 1.6$ for axle steel; $k = 1.1$ and 1.3 for wrought iron. A number of investigations have been made on fillet effect in fatigue(104, 71, 77, 67, 95, 7, 73, 107, 76, 91, 97, 96), the activity being perhaps partly due to the practical importance of fillet effect in connection with shafting. These results are shown in Fig. 22, and attention is again called to the fact that values of stress-concentration factors obtained from fatigue tests are considerably lower than corresponding photo-elastic results.

For fillets in torsion, an analytical solution is available(**112**) and also experimental confirmation by an electrical analogy method(**43**).

Notches:

Inglis(**41**) has extended his analytical solution of the stress concentration due to an elliptical hole to cover the case of a notch having the form of half of an ellipse, neglecting the compressive stresses existing normal to the axis. The stress-concentration factor then becomes, as in the case of the elliptical hole, $k = 1 + 2a/b$. The stress-concentration factor must also depend on the ratio of the depth of notch to the width of the plate. Assuming this relation to be similar to that for holes,(**84**) the theoretical curve in Fig. 24 has been drawn. Strain gage measurements over small gage lengths gave experimental confirmation of the presence of high stress concentration at the bottom of a notch(**85**). Photo-elastic tests(**38**) have also been made on the effect of notches, particularly as applied to the type of notch used in impact test specimens. These and other similar tests show that the significant dimensions of the notch are the depth and radius at the bottom of the notch, and that if these dimensions are kept constant, the shape of the notch has little effect on the stress concentration.

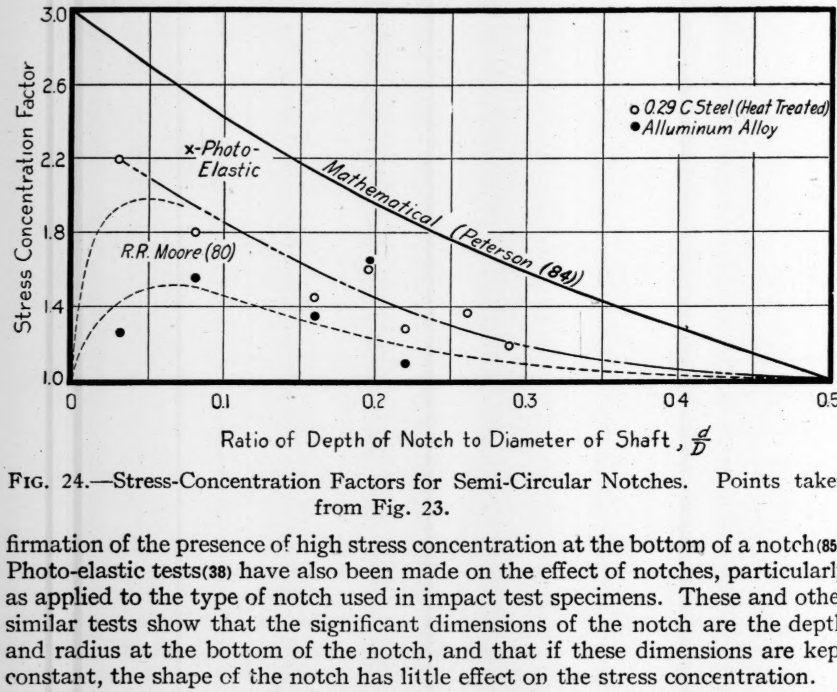

FIG. 24.—Stress-Concentration Factors for Semi-Circular Notches. Points taken from Fig. 23.

Fatigue tests on notch effect have been made by several investigators(**82, 73, 80, 81, 11, 56, 102**). Some of the results are shown in Fig. 23, from which data are taken to construct Fig. 24. A special phase of the notch problem is the stress-concentration effect of screw threads. It is interesting to note that a much lower stress concentration factor is found for continuous threads than for a corresponding single groove of thread form, the following values of k being obtained(**82**):

¼ in., 28 threads per inch (single groove)	**4.26**
¼ in., 28 threads per inch (threads)	**1.19**
⅜ in., 24 threads per inch (single groove)	**2.43**
⅝ in., 24 threads per inch (threads)	**1.38**

A stress concentration factor $k = 1.46$ has been obtained for Whitworth threads(95). The tendency of threaded specimens to fail at the end of the threads makes it difficult to obtain representative tests of the threads proper.

Another interesting phase of the notch problem is the effect of very small notches such as tool marks and scratches(28, 50, 73, 102, 114). The stress concentration factors obtained for very small notches are considerably lower than for grooves of moderate depth(102). This tendency for very small notches to approach zero effect is contrary to mathematical analysis, but is in agreement with results obtained on the effect of holes, as previously discussed. The effect of surface finish may be estimated from the following data:

0.49-PER-CENT CARBON STEEL (MOORE (73))	
Rough turned	1.21
Smooth turned	1.19
Ground	1.11
Emery paper	1.06

0.33-PER-CENT CARBON STEEL (THOMAS (102))	
Turned	1.14
Coarse file	1.23
Smooth file	1.09
Coarse emery	1.06
Fine emery	1.02
Fine ground	1.04

The notches and scratches discussed were in all cases perpendicular to the direction of stressing, resulting in maximum stress-concentration effect. If the scratches are parallel to the direction of stressing, practically no effect may be expected. The presence of a rough skin, such as in leaf springs, reduces the endurance limit to less than one-half that obtained from standard machined specimens having polished surfaces(6, 36).[1] For a keyway subjected to alternating torsion, a stress concentration factor $k = 1.27$ has been obtained for 0.65-per-cent carbon steel(20).

For determining the stress concentration effect of various cross-sections in torsion, a soap film method has been successfully used(27), the analogy being due to Prandtl.

Conclusions:

Stress concentration factors obtained in fatigue tests are in all cases lower than corresponding values obtained analytically or photo-elastically.

Fatigue stress-concentration factors tend to follow the same general tendencies in terms of dimensional relations as indicated by theory, except in the case of very fine discontinuities where the fatigue values approach a condition of no effect.

Fatigue stress-concentration factors depend also on material, but with the limited information available, no satisfactory correlation can be found with any properties of material, such as ductility or hardness.

The fatigue stress-concentration factors for cast iron are considerably lower than for steels, the reason apparently being that the flakes and holes inherent in cast iron produce considerable stress concentration, so that the effect of an imposed discontinuity is somewhat masked.

Some of the alloy steels, such as chrome nickel, seem to be more sensitive to stress-concentration effects, a property which has been called the "tenderness"(68) of a material.

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[1] NOTE BY H. F. MOORE.—The reduction of endurance limit by a rough skin depends on the material, and is, in general, smaller for soft steel than for hard steel.

CORROSION-FATIGUE

The corrosion-fatigue phase of the study of the fatigue of metals is of extreme importance, but it has been of such recent development, and new facts are being brought to light so rapidly that it does not seem possible to give any summary of present-day views which would be apt to prove of value even for the near future(62, 63, 64, 65, 66).

In a very general way it may be said that the *simultaneous* action of repeated stress and a corroding agent may very greatly reduce the fatigue strength of a metal.

With fresh water as the corroding agent the corrosion-fatigue limit for carbon steel and ordinary alloy steels ranges from about two-thirds to less than 15 per cent of the endurance limit in air. With salt water the corrosion-fatigue limit for steel is still lower. The corrosion-fatigue limit is surprisingly little affected by heat treatment or chemical composition, except as such heat treatment or composition affects corrosion resistance. For "stainless" (high chromium) and other corrosion-resistant steels, the corrosion-fatigue limit is higher than for carbon steels and other alloy steels.

The study of protection against corrosion-fatigue is proceeding along three lines:

1. A study of alloying elements which increase the resistance of a metal to corrosion.
2. A study of protective coatings for metals, and
3. The introduction of chemical inhibitors or retardants of corrosion into the water or other corroding medium.

All the three lines give promise of useful development(86, 93).

THE SIGNIFICANCE OF FATIGUE TEST RESULTS

BY H. F. MOORE[1]

One of the problems always before the testing engineer is the problem of properly judging the significance of his test results. In nearly all cases laboratory tests are, in fact, accelerated tests as compared with the final test of satisfactory service. Experiments in many fields of testing have shown that the significance of accelerated tests is always a matter involving some uncertainty. Fatigue tests usually apply cycles of stress to specimens very rapidly and continuously, so that in a few hours, or days, the specimen undergoes as many cycles of stress as the proposed machine member would be called on to withstand in its normal period of service.

So long as questions of corrosion and high temperature do not come in, experimental evidence(69, 71, 73) seems to indicate that the time element is not of great consequence over the range covered from ordinary machine service on the one hand to speed of laboratory testing on the other. However, if the factor of corrosion or the factor of creep under steady load appears, the time element may become of importance and the ordinary fatigue test may not alone serve as a criterion for satisfactory performance in practice. Moreover, it must always be borne in mind that the failure by spreading fracture, commonly known as fatigue, is *not the only way* in which metals fail. Metals may fail by plastic flow beyond the limit of elastic strength. Where this method is indicated as more likely to occur than fatigue, some criterion of elastic strength—elastic limit, proportional limit or yield point—would be indicated as the criterion for service strength.

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Where the danger of failure seems to be from creep under steady load, some form of creep limit would seem to be the criterion for service strength. It is to be hoped that practice methods of determining such a limit will soon be developed.

The question of apparatus to resist the energy of rather suddenly applied loads is quite a puzzling one. If it is primarily important that there should be no appreciable permanent distortion of the part, it would seem necessary that the energy of the load should not exceed the energy stored when the member was stressed to its limit of elastic strength; in other words, elastic strength would be the criterion to be used. If slight permanent distortion is not objectionable and energy loads are to be met only rarely, a combination of tensile (or possible shearing) strength with a good degree of ductility would seem to be a criterion for satisfactory service—a criterion whose exact specification for a metal is a matter of considerable uncertainty.

If the energy loads are repeated very many times a necessary criterion of satisfactory service would be that the energy absorbed by a member shall not set up stresses above the endurance limit of the material. Here the endurance limit would seem to be a vital criterion for satisfactory service.

Above all it is important that the designer of structures and machines and the user of materials get into the habit of mind of considering the possibilities of more than one kind of failure. It will be of little avail to design a machine part to resist repeated stress if the real danger of failure is through creep or plastic flow. It will be of little avail to design a structural part to resist repeated stress if the danger of failure comes from the rare but heavy accidental overload. No one test of strength will suffice for all cases; elastic strength, energy absorbing capacity, resistance to creep under steady load, fracture (especially of brittle materials) under a single load, and progressive fracture under repeated loading must all be taken into account.

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REPORT OF COMMITTEE B-1
ON
COPPER WIRE

During the past year, Committee B-1 on Copper Wire held one meeting in New York City on April 22 at which final decision was reached on the standardization of grooved wire for use in mines. This project was undertaken at the request of the National Electric Manufacturers' Association and in cooperation jointly with that association, the American Mining Congress and the American Electric Railway Association and the A.S.T.M. Unanimous agreement was reported by the Conference Committee representing the interested bodies on the design and dimensions of grooved trolley wire of 350,000 cir. mils cross-section and upon the required tensile properties of this wire when made of copper and when made of the two qualities of bronze used for trolley wire.

As a result of this agreement Committee B-1 is recommending for immediate adoption revisions in two standard specifications under its jurisdiction, as mentioned later in the report. Attention is especially called to the fact that the recommended revisions, given in detail below, do not alter either specification in its technical requirements but merely add a new and larger size of grooved wire suitable for service in mines. The revision also changes the manner of stating the requirements for strength and elongation of grooved wire to agree with the manner of stating these requirements now used for grooved bronze wire. It is desirable that the amendments be included in the specifications in order to have them appear in the 1930 edition of the Book of Standards. It is recommended that these revisions be adopted immediately and that the specifications as revised be continued as standard provided the other three bodies concerned in the work signify their agreement. Otherwise, the revisions are offered as tentative with the expectation of becoming standard a year hence. It is confidently expected that the acceptance of this recommendation will be favorable since the representatives of the cooperating bodies have undertaken to secure such agreement.

The committee is unable to report any progress in the matter of specifications for wire and cable for electric power transmission lines.

RECOMMENDATIONS AFFECTING STANDARDS

The committee recommends that the following revisions in two of its standards be adopted immediately and the specifications as revised continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption:

Standard Specifications for Round and Grooved Hard-Drawn Copper Trolley Wire (B 47 - 27):[1]

Section 6 (*a*).—Change from its present form: namely,

> 6. (*a*) The physical tests for grooved wire shall be made in the same manner as those upon the round wire. The tensile strength of grooved wire shall be at least 95 per cent of that required for round wire of the same nominal cross-sectional area; the elongation shall be the same as that required for round wire of the same nominal cross-sectional area. The twist test shall be omitted.

to read as follows:

> 6. (*a*) The physical tests for grooved wire shall be made in the same manner as those upon the round wire. The tensile strength and elongation of grooved wire shall not be less than the values given in Table II. The twist test shall be omitted.

TABLE II.—VALUES FOR TENSILE STRENGTH AND ELONGATION OF GROOVED WIRE.

AREA, CIRCULAR MILS	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 10 IN., PER CENT
350 000	42 800	4.50
300 000	44 700	4.50
211 600	46 600	3.75
168 100	48 500	3.25
133 225	50 200	2.80

Figure 1.—Add to the present figure, which shows the standardized sections for grooved trolley wire, an additional section for grooved wire of 350,000 cir. mils in area, as shown in the accompanying Fig. 1.

Section 11 (*a*).—Add to the table after Paragraph (*a*) a new line of requirements for grooved wire of 350,000 cir. mils in area, reading as follows:

NOMINAL AREA, CIRCULAR MILS	ACTUAL AREA, SQ. IN.	CALCULATED WEIGHT BASED ON ACTUAL AREA, LB. PER MILE
350 000	0.2758	5612

Standard Specifications for Bronze Trolley Wire (B 9 - 29):[2]

Table II.—Through an oversight there was included in Table II requirements for tensile strength and elongation of grooved wire of

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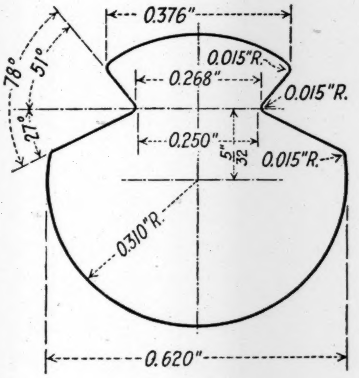
[1] 1927 Book of A.S.T.M. Standards, Part I, p. 574.

[2] 1929 Supplement to Book of A.S.T.M. Standards, p. 90.

105,625 cir. mils in area. The Conference Committee had voted not to standardize grooved wire of this area and data concerning it had been removed from all other parts of the specifications but inadvertently had been allowed to remain in Table II. The A.E.R.A. has deleted this size from its specifications to correct this error. Similar action is now recommended in the Standard Specifications B 9 – 29.



Grooved Wire
Nominal Cir. Mils, 350 000
Actual Area, 0.2758 sq. in.
Calculated Weight, 5612 lb. per mile.

FIG. 1.—Section of Grooved Trolley Wire, 350,000 cir. mils in area.

It is also recommended that minimum requirements on tensile properties for grooved wire of 350,000 cir. mils in area be added to this table. The committee therefore recommends that Table II be changed by the addition of the following italicized figures and the omission of those in brackets:

	HIGH-STRENGTH BRONZE WIRE		MEDIUM-STRENGTH BRONZE WIRE	
AREA, CIRCULAR MILS	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 10 IN., PER CENT	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 10 IN., PER CENT
350 000............	*62 000*	*4.00*	*56 000*	*4.00*
[105 625............	76 000	2.00	68 000	2.00]

Section 11.—Add to the table in Paragraph (*a*) the same requirements for grooved wire of 350,000 cir. mils area as recommended in Section 11 (*a*) of Specifications B 47 – 27, given above.

Figure 1.—Add to the present figure, which shows the standardized sections for grooved trolley wire, an additional section for grooved wire of 350,000 cir. mils shown in the accompanying Fig. 1.

The election of officers resulted in the re-election of the present incumbents.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS OF STANDARDS			
Standard Specifications for Round and Grooved Hard-Drawn Copper Trolley Wire (B 47 – 27), immediate adoption	17	0	2
Standard Specifications for Bronze Trolley Wire (B 9 – 29), immediate adoption	17	0	2

This report has been submitted to letter ballot of the committee, which consists of 19 members; 19 members returned their ballots, of whom 18 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

J. A. CAPP,
Chairman.

EDITORIAL NOTE

The proposed immediate revision of the Standard Specifications for Round and Grooved Hard-Drawn Copper Trolley Wire and for Bronze Trolley Wire was approved at the annual meeting by a unanimous vote and was subsequently adopted by letter ballot of the Society on September 2, 1930. The specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, pages 652 and 646, respectively.

REPORT OF COMMITTEE B-2
ON
NON-FERROUS METALS AND ALLOYS

The principal activity of Committee B-2 during the past year has been centered in Subcommittee XV on Die-Cast Metals and Alloys and in Subcommittee VII on Methods of Chemical Analysis.

No recommendations affecting standards or tentative standards are being made.

REORGANIZATION ACTIVITIES

Reorganization activities outlined in the report of last year[1] have been carried through with the exception of the proposed new Committee to take over work on alloys of Tin, Lead, Zinc and Antimony, which project was abandoned. On the other hand the work of Subcommittee XV has become so extensive, and is directed along so many lines by efficient groups of cooperators, that it has been decided to place that work in the future under the direction of a new and independent Committee B-6 on Die-Cast Metals and Alloys. This reorganization is one of form only which will expedite the work by eliminating certain steps in routine Society procedure. The proposed scope of the new Committee B-6 will include the accumulation and dissemination of information on, and the preparation of specifications for, die-cast metals and alloys, including aluminum-base, zinc-base, lead-base, tin-base, and copper-base alloys.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee IV on White Metals—Tin, Lead and Zinc (G. H. Clamer, chairman).—This subcommittee held one formal meeting during the year. Information regarding the various studies now being made at various research laboratories on bearings and bearing metals was interchanged. At the U. S. Bureau of Standards an especially extensive series of tests on babbitt metals is under way, including hardness, impact and compressive strength, wear and pounding at normal temperatures and at temperatures up to 200° C. Wear in service on army trucks is also to be studied. Pronounced changes are being made in the types of journal bearings used in automotive construction. Preliminary steps were also taken toward studying the properties of type metal prior to the writing of specifications, and of the so-called terne metal, namely, lead-tin alloys used for coating purposes.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 186 (1929).

Subcommittee VII on Chemical Analysis (H. A. Bedworth, chairman).—In conjunction with Subcommittee XIV on Precious Metals and Alloys, cooperative analyses of standard samples of silver solders have been completed and proposed methods of chemical analysis of silver solders have been submitted to the subcommittee for vote before submission as a tentative standard. Cooperative analyses are nearing completion of standard samples of zinc-base die-casting alloys; this work is being carried out in conjunction with Subcommittee XV and the U. S. Bureau of Standards. It is recommended that the tentative revision of the standard Methods of Chemical Analysis of Manganese Bronze, (B 27-19) be continued as tentative for another year pending results of work being done at the Bureau of Standards. It is also recommended that the Tentative Methods for Chemical Analysis of Aluminum and Light Aluminum Alloys (B 40-28 T) be continued as tentative for another year pending proposed changes in the specifications for aluminum and aluminum alloys under the jurisdiction of Committee B-7 on Light Metals and Alloys.

Subcommittee XII on Metallic Fluxes and Deoxidizers (W. M. Corse, temporary chairman).—This subcommittee held one formal meeting at which the relationship between its activities and those of research groups of other technical societies was considered. In order to avoid duplication of effort, a joint meeting will be arranged with as many of these groups as will respond.

Subcommittee XIV on Precious Metals and Alloys (R. H. Leach, chairman).—Activities have been confined to a continuing study of the uses of silver solders with different metals and alloys, as well as a joint study with Subcommittee VII on methods of chemical analysis of silver solders.

Subcommittee XV on Die-Cast Metals and Alloys (H. A. Anderson, chairman).—Considerable progress has been made during the past year by this subcommittee on the comprehensive series of tests on aluminum-base and zinc-base die-casting alloys. Studies of the chemical composition and of the physical properties of nine zinc-base alloys as cast by six producers have been completed and representative tables showing the results of these tests appear in the report of the subcommittee appended hereto. Test racks containing die-cast specimens of both the aluminum-base and zinc-base alloys for atmospheric exposure were placed at ten locations during the past year.

Data showing the action of zinc-base die-cast alloys when exposed to water-vapor atmosphere at elevated temperatures and immersion in heated paraffin are given in the report appended hereto, which also includes a statistical analysis of the test data on aluminum-base die-cast specimens from each of the five producers. The report also includes a brief discussion of the metallography of zinc-base die-cast alloys by W. M. Peirce as Appendix I.

The committee takes pleasure in submitting a revision and amplification of Campbell's List of Alloys originally published in 1922. Data on physical properties of some typical alloy compositions are included. The enlarged List as prepared by Mr. William Campbell appears as Appendix II to this report.

This report has been submitted to letter ballot of the committee which consists of 125 members; 103 members returned their ballots, of whom 99 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

WILLIAM CAMPBELL,
Chairman.

E. E. THUM,
Secretary.

REPORT OF SUBCOMMITTEE XV ON DIE-CAST METALS AND ALLOYS

Subcommittee XV held four meetings during the past year with an average attendance of 40 persons. In addition to the interchange of information resulting from these gatherings there have been eight bulletins giving summarized data of the findings of the cooperating laboratories circulated to the members. The quality and quantity of laboratory studies has been maintained at the same high level as characterized the committee's activities during its first two years.

Initial studies on the aluminum-base alloys, representing twelve commercial compositions and produced by five plants, had been nearly completed at the time of last year's report. Further work has included corrosion studies and the establishment of preferred methods of physical testing.

Table I.—Results of Chemical Analyses of Zinc-Base Die-Cast Specimens From Producer B as Analyzed by Laboratories A and Z.

Alloy	Laboratory	Chemical Composition, per cent									
		Aluminum	Copper	Magnesium	Manganese	Lead	Cadmium	Tin	Iron	Antimony	Zinc (by difference)
No. XIII.......	A	0.32	4.65	nil	nil	0.034	0.050	0.030	0.067	0.008	94.841
	Z	0.35	4.50	nil	0.001−	0.044	0.045	0.029	0.046	0.01−	94.981
No. XIV.......	A	3.85	3.21	nil	nil	0.029	0.031	0.030	0.034	0.007	92.809
	Z	3.90	3.15	nil	0.001−	0.045	0.040	0.029	0.030	0.01−	92.801
No. XV........	A	4.06	2.97	0.09	nil	0.026	0.075	nil	0.038	0.007	97.734
	Z	4.05	2.95	0.09	0.001−	0.028	0.038	0.010	0.030	0.01−	92.799
No. XVI.......	A	4.01	2.99	0.08	nil	0.042	0 011	nil	0.038	0.003	92.826
	Z	4.00	3.05	0.09	[a]	0.050	0.003	0.0033	0.036	0.01−	92.763
No. XVII......	A	3.05	3.00	0.30	nil	0.026	0.052	nil	0.030	0.007	93.535
	Z	3.15	2.85	0.33	0.001−	0.031	0.036	0.001	0.027	0.01−	93.570
No. XVIII.....	A	0.63	2.10	nil	nil	0.42	0.20	5.86	0.054	0.009	90.727
	Z	0.55	2.35	0.0025	0.001−	0.45	0.18	5.70	0.21	0.028−	90.530
No XIX.......	A	4.22	2.18	0.07	nil	0.046	0.008	nil	0.042	0.005	93.429
	Z	4.15	2.30	0.10	0.001−	0.044	0.002	0.0027	0.034	0.01−	93.365[b]
No. XX........	A	3.98	3.11	nil	nil	0.24	0.038	0.13	0.14	0.008	92.354
	Z	3.80	3.15	nil	0.001−	0.25	0.025	0.12	0.30	0.01	92.350
No. XXI.......	A	3.92	2.96	0.11	nil	0.004	0.010	nil	0.026	0.007	92.963
	Z	4.00	3.00	0.13	0.001−	0.0034	0.004	0.002	0.023	0.01	92.833

[a] Not determined.
[b] Nickel 0.002 per cent.

Most of the past year's activities have been studies on the nine zinc-base alloys as cast by six producers. Tensile strength, ductility, hardness and impact tests on these alloys and certain accelerated corrosion tests, such as exposure in water-vapor atmospheres at elevated temperatures and immersion in heated paraffin, have yielded information which is having important effect on the commercial production of high-grade zinc.

General indications regarding the relative merits of various zinc-base die-castings for various uses are discussed in a paper[1] contributed by D. L. Colwell at this annual meeting, and the commercial applications of these alloys in another paper[2] by Charles Pack. Both of these papers were prepared with the cooperation of Subcommittee XV.

Representative data showing the properties of the zinc-base alloys as tested under various conditions appear in Tables I to III and are plotted in Figs. 1 to 5.

TABLE II.—EXPANSION TESTS ON ZINC-BASE DIE-CAST SPECIMENS.

Castings Made by Producer B and Tested by the American Brass Co. Laboratories, Waterbury, Conn.

Values given show average total expansion in inches measured over full length of specimens.
Flat indicates flat tensile specimens, 9 in. in length.
Round indicates round tensile specimens, 9 in. in length.
Impact indicates impact specimens, 6 in. in length.

Alloy	After 30-days Exposure in Water Vapor at 70° C.			After 60-days Exposure in Water Vapor at 70° C.			After 20-days Exposure in Water Vapor at 95° C.			After 10-days Immersion in Paraffin at 95° C.			After 20-days Immersion in Paraffin at 95° C.		
	Expansion, in.			Expansion, in.			Expansion, in.			Expansion, in.			Expansion, in.		
	Flat	Round	Impact	Flat	Round	Impact	Flat	Round	Impact	Flat	Round	Impact	Flat	Round	Impact
No. XIII	0.037	0.018	0.018	0.053	0.027	0.029	0.113	0.035	0.044	0.001	0.002	0.000	0.002	0.002	0.001
No. XIV	0.158	0.089	0.103	....	0.158	....	....	0.161	....	0.029	0.030	0.024	0.033	0.033	0.022
No. XV	0.026	0.028	0.018	0.041	0.038	0.024	0.070	0.056	0.040	0.019	0.020	0.014	0.026	0.024	0.016
No. XVI	0.025	0.025	0.022	0.036	0.036	0.025	0.073	0.054	0.040	0.019	0.019	0.014	0.023	0.024	0.015
No. XVII	0.017	0.018	0.015	0.029	0.023	0.016	0.067	0.044	0.033	0.016	0.017	0.009	0.020	0.019	0.013
No. XVIII	0.057	0.056	0.065	0.085	0.078	0.076	0.379	0.283	0.276	0.004	0.004	0.003	0.008	0.005	0.005
No. XIX	0.013	0.015	0.015	0.023	0.021	0.016	0.054	0.041	0.030	0.010	0.009	0.008	0.014	0.013	0.011
No. XX	....	0.105	....	....	....	....	0.68[a]	0.135[a]	0.192	0.028	0.028	0.020	0.032	0.034	0.019
No. XXI	0.012	0.014	0.015	0.014	0.019	0.010	0.033	0.026	0.018	0.019	0.018	0.014	0.023	0.023	0.016

[a] Expansion in 5 days only.

Test racks containing die-cast specimens of both the aluminum-base and zinc-base die-casting alloys for atmospheric exposure were placed in position during the months of June and July, 1929, at the ten locations listed in the 1929 report.[3] The diversity of the climatic conditions represented by these locations is apparent in that they include Cambridge, Mass., Altoona, Pa., Hanover, N. M.; and Coco Solo, Panama Canal Zone. A typical test rack erected on the roof of a building in New York City is shown in Fig. 6. Samples will be tested after exposures of 1, 3 and 5 years by a number of laboratories which have cooperated in previous studies, and the results should afford conclusive evidence regarding the usefulness of various accelerated corrosion tests, as well as regarding the durability of the die castings under the various climatic conditions.

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[1] D. L. Colwell, "Development of Zinc-Base Die-Casting Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 473 (1930).

[2] Charles Pack, "Advances in Die-Cast Metals for Automotive Uses," presented before the Detroit Regional Meeting, American Society for Testing Materials, in March, 1930.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 200 (1929).

The disintegration of certain types of zinc-base, die-casting alloys has been a major deterrent to their wider use. This disintegration is due to intercrystalline oxidation. The susceptibility of the alloys to this intercrystalline oxidation is affected by the conditions under which the structural change, in which the beta phase transforms into alpha plus gamma phase, occurs. This growth and oxidation of zinc-base die castings in the presence of water vapor has been shown to be accelerated by the presence of tin and lead as impurities and to be reduced by the addition of small quantities of magnesium. It has been clearly established that the use of zinc of the highest purity commercially obtainable (0.02 per cent maximum impurities) is essential where the maximum longevity is expected in the presence of moisture. A brief discussion of the metallography of zinc-base die-casting alloys is presented in a paper by W. M. Peirce, which appears as Appendix I.

TABLE III.—TYPICAL PHYSICAL DATA SUMMARY OF TEST OF ZINC-BASE DIE-CAST SPECIMENS FROM PRODUCER B, TESTED BY THE AMERICAN BRASS CO. LABORATORIES.

Alloy	Average Tensile Strength, lb. per sq. in.		Average Deviation of Individual Tensile Strength, per cent		Minimum Tensile Strength, lb. per sq. in.		Average Elongation in 2 in., per cent		Average Impact, Charpy, ft-lb.	Tensile Fractures (ten specimens per alloy)		
	Flat	Round	Flat	Round	Flat	Round	Flat	Round		Sound Metal	Blow Holes	Broke in Fillet
INITIAL PHYSICAL TESTS												
No. XIII..	27 760	29 300	4.2	4.9	26 300	26 700	0.40	0.80	0.59	5	5	0
No. XIV..	43 180	45 160	1.0	9.7	42 300	44 600	0.65	2.05	1.67	0	10	0
No. XV...	43 840	45 840	8.2	1.6	34 800	44 600	1.20	1.95	2.53	0	10	0
No. XVI..	47 360	47 740	3.4	1.5	45 400	46 900	1.35	2.85	4.16	0	10	0
No. XVII.	33 780	40 360	1.0	2.0	23 200	38 800	0.25	0.25	0.95	0	10	0
No. XVIII	23 910	27 140	7.8	3.4	19 950	26 100	0.75	0.75	1.41	0	10	0
No. XIX..	45 840	44 480	4.4	7.9	43 300	43 200	2.10	2.50	7.20	0	10	0
No. XX...	36 420	41 700	12.1	1.8	29 800	40 400	0.60	0.55	1.52	0	10	0
No. XXI..	45 980	47 880	3.7	2.3	41 700	45 500	3.05	5.60	8.27	0	10	0
AFTER 20 DAYS' IMMERSION IN PARAFFIN AT 95° C.												
No. XIII..	28 240	29 020	2.0	2.9	27 700	26 900	0.40	0.30	0.46	5	5	0
No. XIV..	33 920	38 780	7.0	1.6	29 700	37 200	0.50	0.50	0.67	10	0	0
No. XV...	36 820	40 480	15.2	6.0	23 300	36 100	0.55	0.45	0.99	0	10	0
No. XVI..	40 060	42 660	3.6	3.0	38 000	41 300	0.75	0.50	1.06	0	10	0
No. XVII.	30 740	34 280	10.0	7.3	25 500	29 900	0.35	0.40	0.79	0	10	0
No. XVIII	23 060	27 560	12.0	3.2	16 100	25 800	0.75	1.00	0.99	0	10	0
No. XIX..	39 900	40 880	2.1	1.4	37 800	40 000	1.45	1.35	1.73	0	10	0
No. XX...	31 280	37 100	12.0	2.3	24 100	35 000	0.50	0.50	0.52	0	10	0
No. XXI..	39 160	43 180	10.3	5.5	29 100	38 100	0.75	0.90	1.47	0	10	0

TABLE III.—(*Continued*).

Alloy	Average Tensile Strengtb, lb. per sq. in.		Average Deviation of Individual Tensile Strength, per cent		Minimum Tensile Strength, lb. per sq. in.		Average Elongation in 2 in., per cent		Average Impact, Charpy, ft-lb.	Appearance of Specimens	
	Flat	Round	Flat	Round	Flat	Round	Flat	Round		Flat	Round
AFTER 30 DAYS' EXPOSURE IN WATER VAPOR AT 70° C.											
No. XIII..	8 740	8 680	8.6	11.7	7 500	6 900	0.15	0.15	0.25	Deep corrosion	Deep corrosion
No. XIV..	7 180[a]	11 700	7.5	5.5	6 100	10 700	0.06	0.10	0.17	“ “	“ “
No. XV..	32 540	34 040	5.1	2.6	30 000	31 800	0.15	0.15	0.44	“ “	“ “
No. XVI..	30 140	35 540	5.2	4.4	28 800	32 700	0.00	0.35	0.43	“ “	“ “
No. XVII.	31 280[b]	33 250[c]	3.3	8.6	29 200	29 500	0.00	0.06	0.51	Slight corrosion	Slight corrosion
No. XVIII	9 940	12 220	2.4	4.0	9 500	11 000	0.15	0.10	0.20	Deep corrosion	Deep corrosion
No. XIX..	31 920	33 600	2.7	1.4	30 600	32 500	0.25	0.30	0.57	“ “	“ “
No. XX...	[d]	18 700[e]	...	...	.....	18 700	....	0.25	....	......	“ “
No. XXI..	44 740	45 740	2.5	4.8	43 100	40 200	0.75	0.65	1.16	Good	Good
AFTER 60 DAYS' EXPOSURE IN WATER VAPOR AT 70° C.											
No. XIII..	8 360	7 160	9.7	13.7	7 300	4 700	0.15	0.05	0.19	Deep corrosion	Deep corrosion
No. XIV..	[d]	3 450[h]	...	33.2	.....	2 300	....	0.00	....	......	“ “
No. XV...	27 340	29 800[a]	5.9	2.9	25 400	28 900	0.00	0.00	0.37	Deep corrosion	“ “
No. XVI..	27 640	30 380	11.0	4.4	21 400	28 000	0.10	0.30	0.37	“ “	“ “
No. XVII.	23 330[f]	26 720	8.1	15.0	19 300	21 200	0.06	0.20	0.43	“ “	“ “
No. XVIII	10 060	10 820	7.6	5.7	8 700	9 400	0.00	0.10	0.18	“ “	“ “
No. XIX..	29 220	29 060	1.8	5.7	28 500	24 900	0.30	0.40	0.46	“ “	“ “
No. XX...	[d]	[d]	...	...	.....	.....	....	....	....	......	......
No. XXI..	43 450[g]	43 340	2.4	6.4	42 100	38 200	0.81	0.70	1.02	Good	Good
AFTER 10 DAYS' EXPOSURE IN WATER VAPOR AT 95° C.											
No. XIII..	5 628	11 230[a]	9.2	14.0[a]	4 050	8 000	0.25	0.25	0.25	Deep corrosion	Deep corrosion
No. XIV..	[d]	8 370[h]	...	1.3[i]	.....	8 200	....	0.42	0.21	......	“ “
No. XV...	23 250	31 740	8.5	2.6	19 600	30 100	0.25	0.50	0.36	Deep corrosion	“ “
No. XVI..	24 540	29 960	3.7	4.3	22 600	28 400	0.25	0.40	0.38	“ “	“ “
No. XVII.	20 300	27 900	12.8	5.1	16 900	24 600	0.25	0.20	0.39	“ “	“ “
No. XVIII	3 832	8 950	12.7	14.0	2 570	6 300	0.15	0.13	0.16	“ “	“ “
No. XIX..	28 260	31 200[a]	6.1	0.32[a]	25 900	31 100	0.75	0.63	0.47	“ “	“ “
No. XX...	[d]	12 850[a]	...	41.0[a]	.....	5 700	....	0.13	....	......	“ “
No. XXI..	40 940	40 480	7.7	4.2	33 400	37 300	0.70	0.40	1.01	Good	Good
AFTER 20 DAYS' EXPOSURE IN WATER VAPOR AT 95° C.											
No. XIII..	6 440	4 850[h]	15.5	15.5	4 800	4 100	0.25	0.25	0.20	Deep corrosion	Deep corrosion
No. XIV..	[d]	[d]	...	...	.....	.....	....	....	....	......	“ “
No. XV...	17 780	26 850[k]	7.75	2.8	16 400	26 000	0.15	0.13	0.33	Deep corrosion	“ “
No. XVI..	21 000	26 680	4.0	1.5	19 000	26 100	0.20	0.25	0.34	“ “	“ “
No. XVII.	20 350[j]	23 300	7.0	6.9	17 500	21 200	0.31	0.10	0.31	“ “	“ “
No. XVIII	3 250[h]	8 630[l]	2.3	18.0	2 500	6 300	0.00	0.08	0.16	“ “	“ “
No. XIX..	23 900	27 380	3.2	2.0	22 800	26 500	0.25	0.08	0.39	“ “	“ “
No. XX...	[d]	[d]	...	...	.....	.....	....	....	....	......	......
No. XXI..	41 340	41 580	3.5	1.4	39 100	40 600	0.95	0.85	0.90	Good	Good

[a] Average of four specimens; one broke in handling.

[b] Average of four specimens; one had very low value (13,000 lb. per sq. in.) and was not included in average.

[c] Average of four specimens; one had very low value (10,200 lb. per sq. in.) and was not included in average.

[d] Specimens corroded all the way through; no test possible.

[e] One specimen only; four broke in handling.

[f] Average of four specimens; one had very low value (13,800 lb. per sq. in.), and was not included in average.

[g] Average of four specimens; one had very low value (30,100 lb. per sq. in.), and was not included in average.

[h] Average of two specimens; three broke in handling.

[i] Average of three specimens, two broke in handling.

[j] Average of four specimens; one had very low value (11,100 lb. per sq. in.), and was not included in average.

[k] Average of four specimens; one had very low value (11,200 lb. per sq. in.), and was not included in average.

[l] Average of four specimens; one had very low value (2800 lb. per sq. in.), and was not included in average.

Organization of a Technical Committee on Presentation of Data of Committee E-1 on Methods of Testing is largely the outgrowth of the utilization, by methods of statistical analysis, of the data furnished by the cooperating laboratories. Objection has been voiced to extending such statistical studies to cover the further test data because of the difficulty of proper metallurgical direction in making the studies. It is

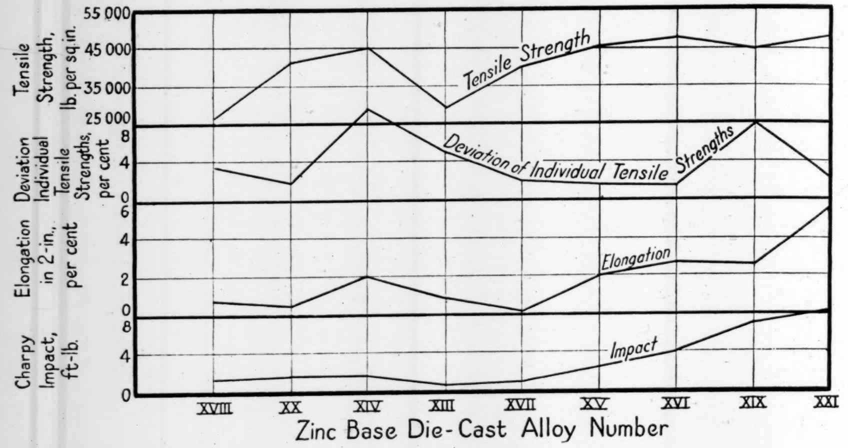

FIG. 1—Average Physical Properties of Nine Zinc-Base, Die-Cast Alloys, Round Specimens from Producer B and Tested by the American Brass Co. Laboratories.

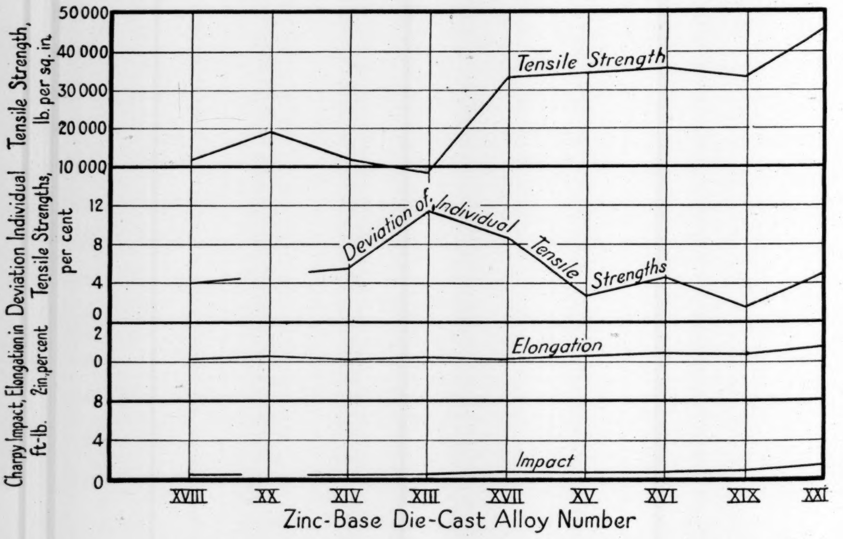

FIG. 2—Average Physical Properties of Nine Zinc-Base, Die-Cast Alloys, Round Specimens from Producer B and Tested by the American Brass Co. Laboratories After 30 Days Exposure in Water Vapor at 70° C.

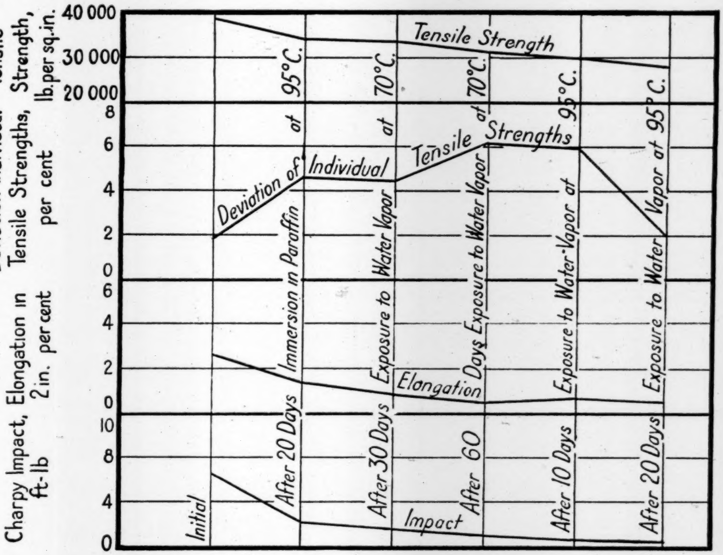

FIG. 3—Change in Physical Properties of Zinc-Base, Die-Cast Alloy No. XIX, from Producer Z Tested by the American Brass Co. Laboratories Under the Influence of Heat With and Without Moisture.

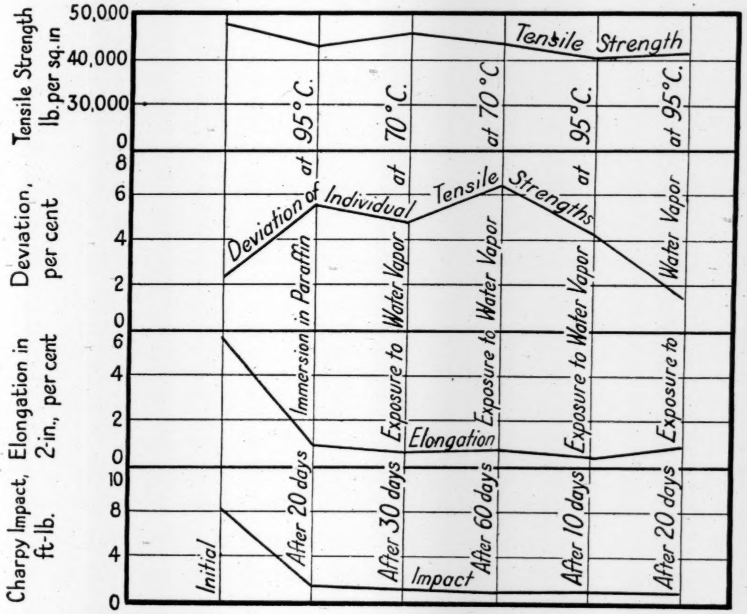

FIG. 4.—Change in Physical Properties of Zinc-Base, Die-Cast Alloy No. XXI, Round Specimens from Producer B Tested by the American Brass Co. Laboratories Under the Influence of Heat With and Without Moisture.

apparently true that considerable simplification of the technique of analyzing data (such as has been done by Committee C-8 on Refractories[1]) will have to precede the extensive use of these methods by numerous cooperators in other committees. However this should not prevent their immediate use by individual manufacturers and users in their appraisal of the merits of various products.

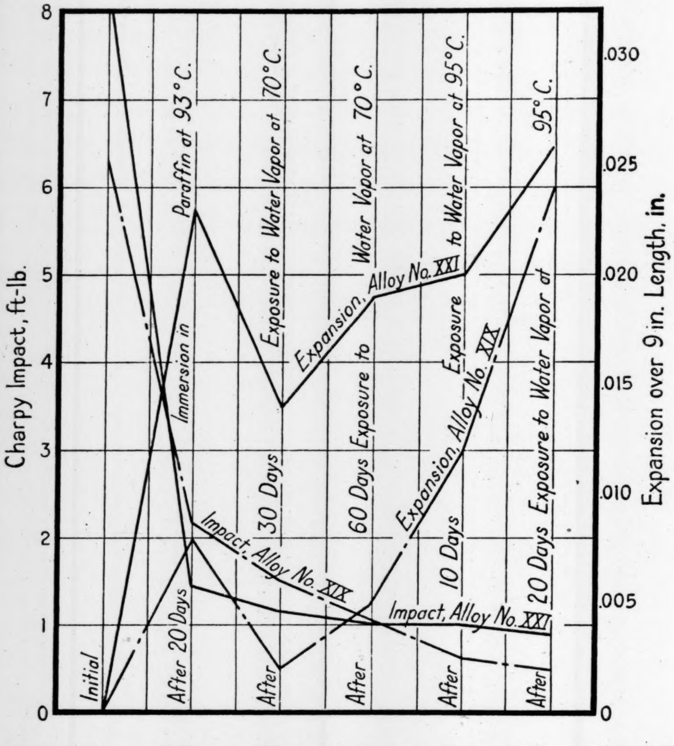

FIG. 5.—Comparison of Expansivity and Loss in Impact Strength of Zinc-Base, Die-Cast Alloys No. XIX from Producer Z and No. XXI from Producer B Tested by the American Brass Co. Laboratories Under the Influence of Heat With and Without Water Vapor.

The judgment of competent engineers must always precede and temper the findings of the statistician but the experience of large industries, such as the insurance companies, other business houses and the telephone companies, have demonstrated conclusively that many erroneous conclusions may be avoided and future trends predicted with reasonable certainity by supplementing the judgment of individuals by modern statistical analyses. The steel industry of Germany is now making extensive use of statistical theory along these lines.

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[1] Manual for Interpretation of Refractory Test Data (1929), Appendix to Report of Committee C-8 on Refractories, see p. 478.

In view of the uncertainty of the subcommittee regarding the desirability of undertaking extensive statistical studies of the available test data, arrangements were made to have typical charts prepared to answer two questions of general interest regarding test methods, namely (1) the relative advantages of standard flat and round test specimens[1] for determining the physical properties of the various alloys, and (2) the usefulness of Rockwell hardness "E" scale for measuring a characteristic of the alloy which would bear a definable relationship to the tensile strength. Results of these studies are presented in Figs. 7 to 12 inclusive, based upon results from two laboratories for the initial tests of aluminum-base die-cast specimens from each of the five producers.

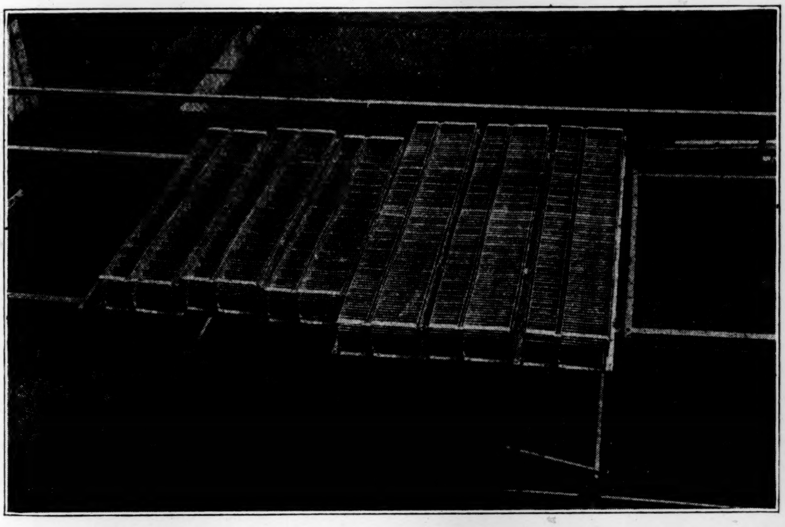

FIG. 6.—Test Racks for Atmospheric Exposure Studies of Aluminum and Zinc-Base, Die-Cast Specimens (this Rack on Roof of Building in New York City); Other Racks at Nine Other Locations Under Different Climatic Conditions.

The round specimen is demonstrated to be more representative of a die-casting alloy in that it yields a higher average tensile strength and a lower standard deviation. This superiority of the round specimen is more apparent in the case of alloy VII (copper 4 per cent, silicon 5 per cent, and balance aluminum) than in the case of the other alloy studied (alloy V, silicon 13 per cent, and balance aluminum). This relationship appears to be the logical result of greater fluidity of

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 203 (1928).

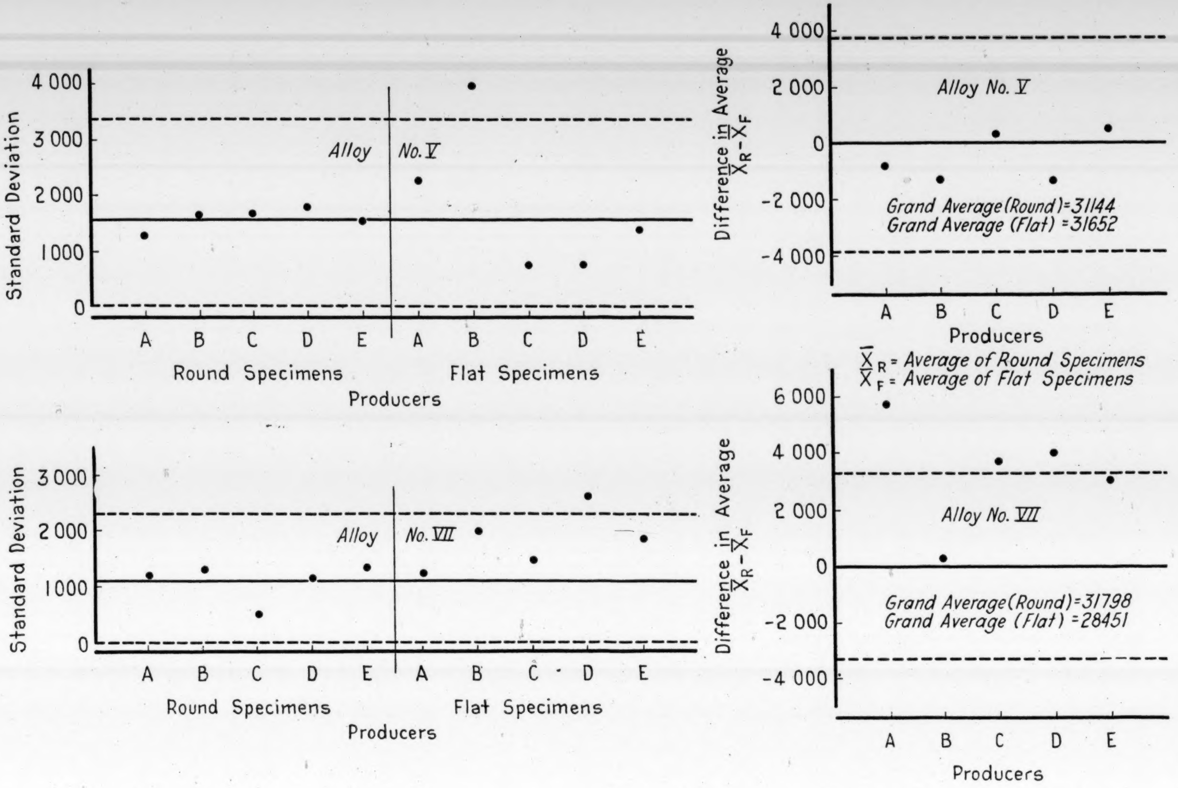

FIG. 7.—Standard Deviations and Differences in Averages of Tensile Strengths for Flat and Round Test Specimens of Aluminum-Base Die-Casting Alloys Nos. V and VII from all Producers, Results by Laboratory U.

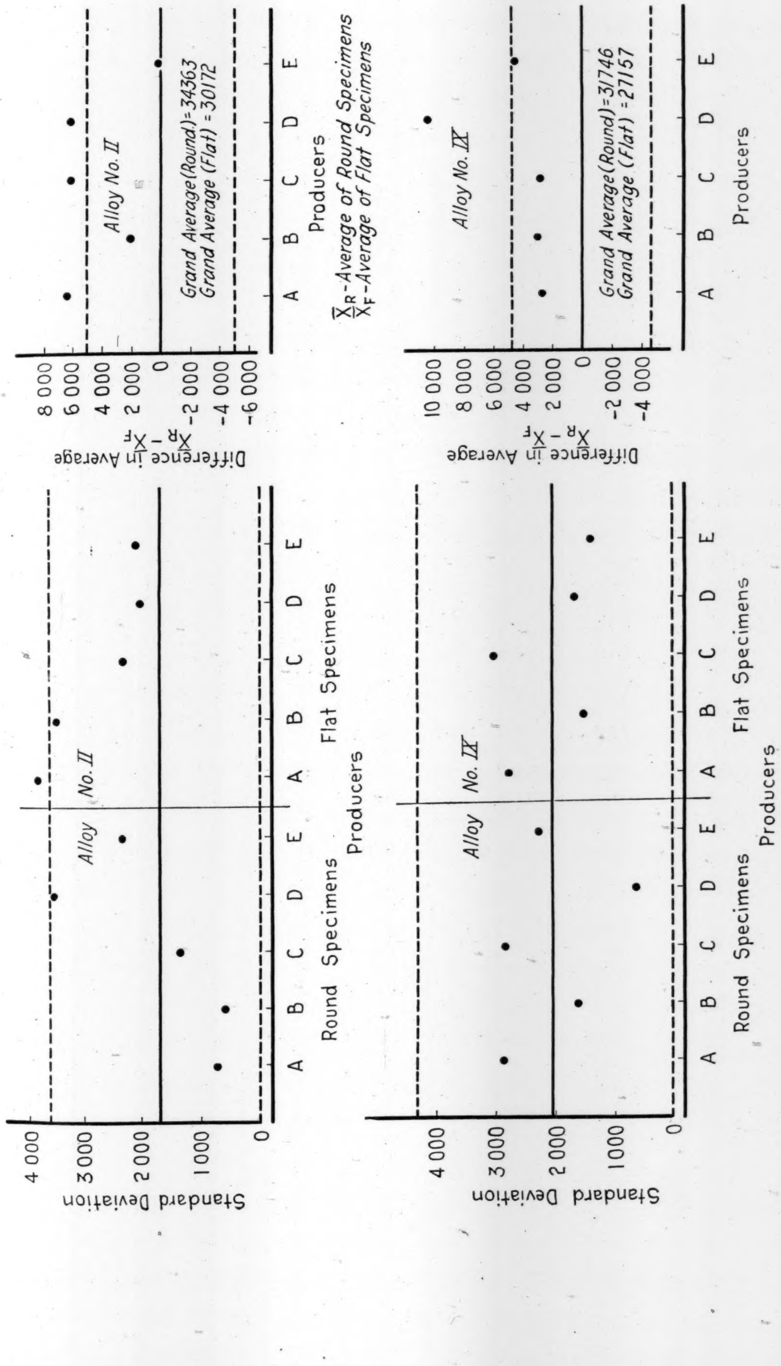

FIG. 8.—Standard Deviations and Differences in Averages of Tensile Strengths for Flat and Round Test Specimens of Aluminum-Base Die-Casting Alloys Nos. II and IX from all Producers, Results by Laboratory U.

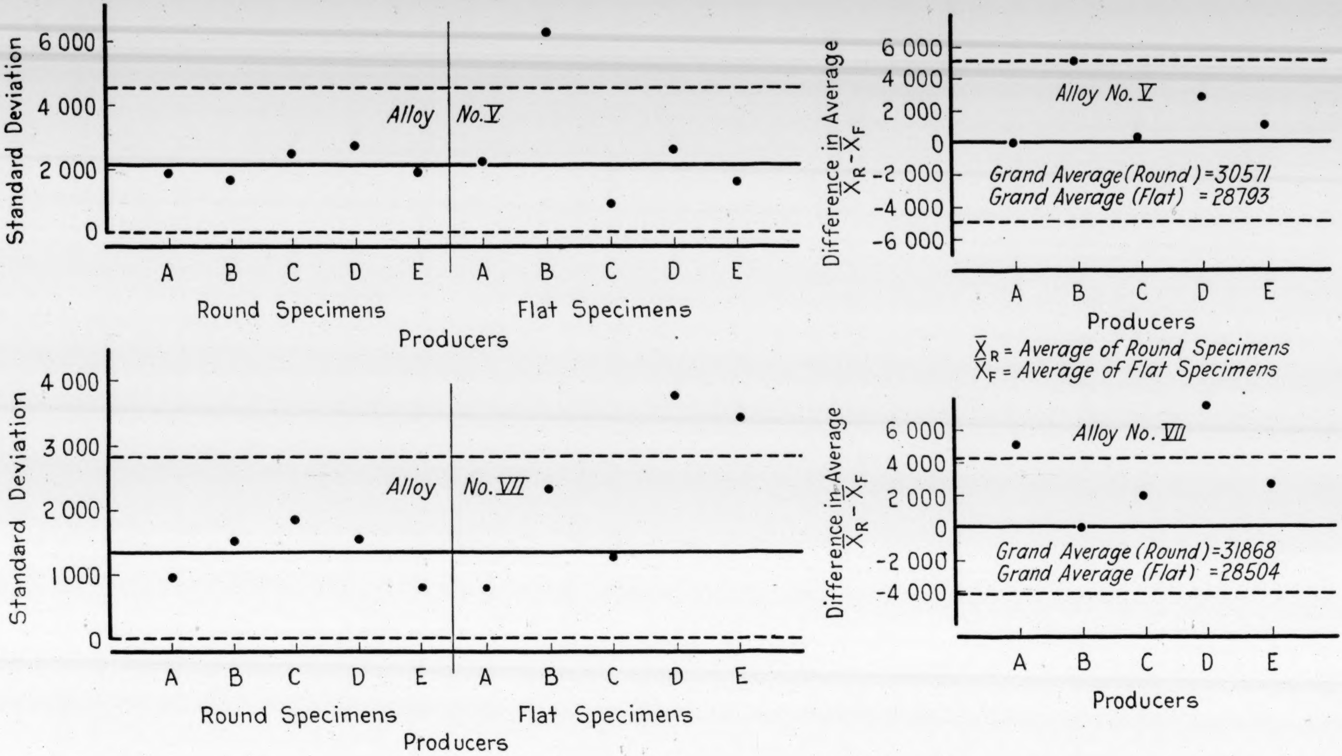

FIG. 9.—Standard Deviations and Differences in Averages of Tensile Strengths for Flat and Round Test Specimens of Aluminum-Base Die-Casting Alloys Nos. V and VII from all Producers, Results by Laboratory B.

the silicon alloy and its consequent ability to fill the flat recess in the die as satisfactorily as the recess for the round specimen.

Information on the usefulness of the Brinell or Rockwell hardness "E" scale for evaluating the tensile strength is less conclusive; however, it is reasonable to assume from Figs. 9 to 12 that the relationship is inconsistent both between strength and either form of hardness and also between Rockwell hardness and Brinell hardness. It would appear that the experimental errors mask the relationship. These

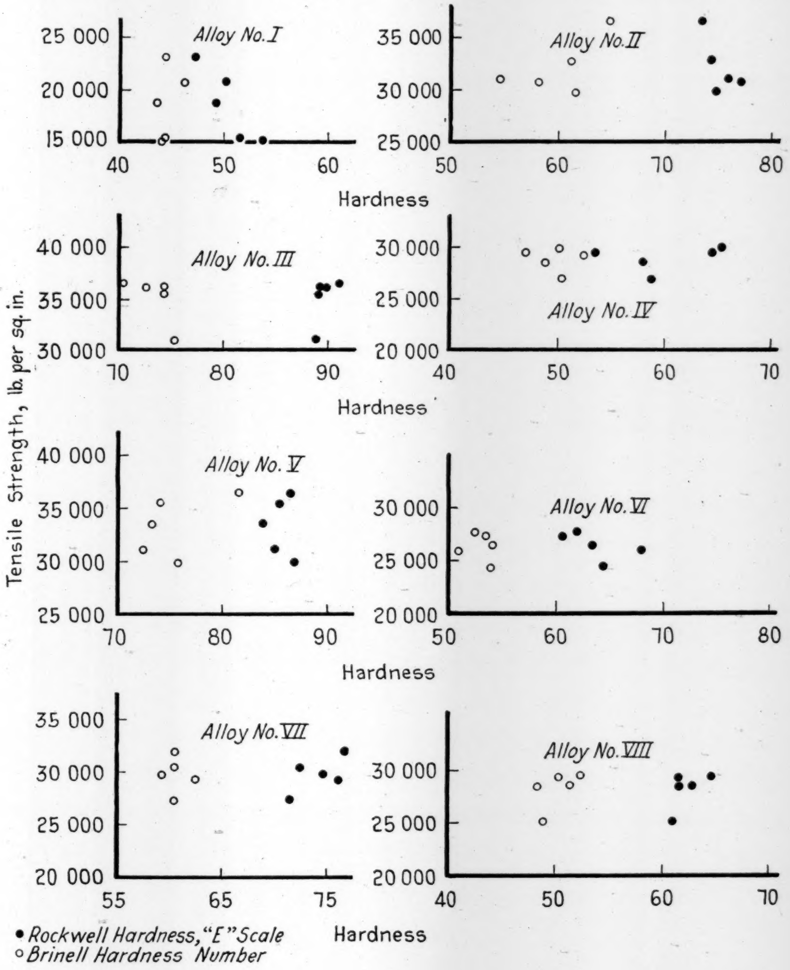

FIG. 10.—Correlation of Tensile Strength with Brinell Hardness Numbers and Rockwell Hardness, "E" Scale, of Aluminum-Base Die-Casting Alloys. Specimens from Producer A, Results by Laboratory N.

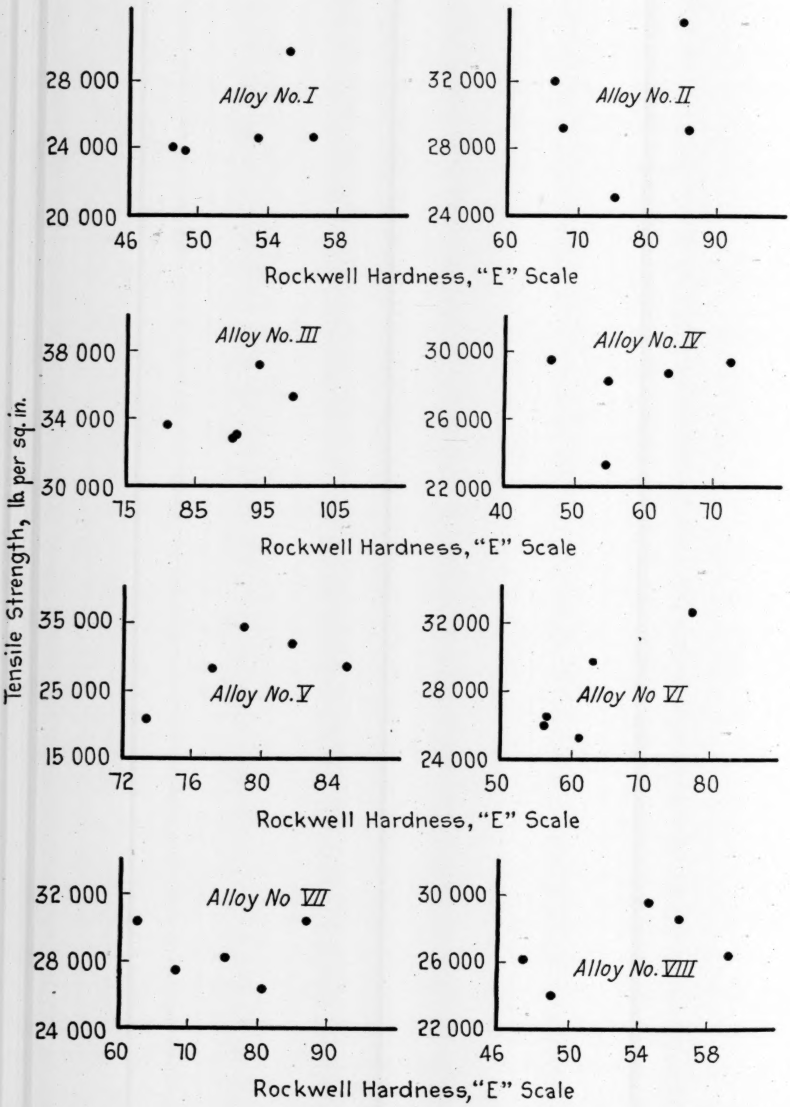

FIG. 11 —Correlation of Tensile Strength with Rockwell Hardness, "E" Scale, of Aluminum-Base Die-Casting Alloys. Flat Specimens from all Producers, Results by Laboratory B.

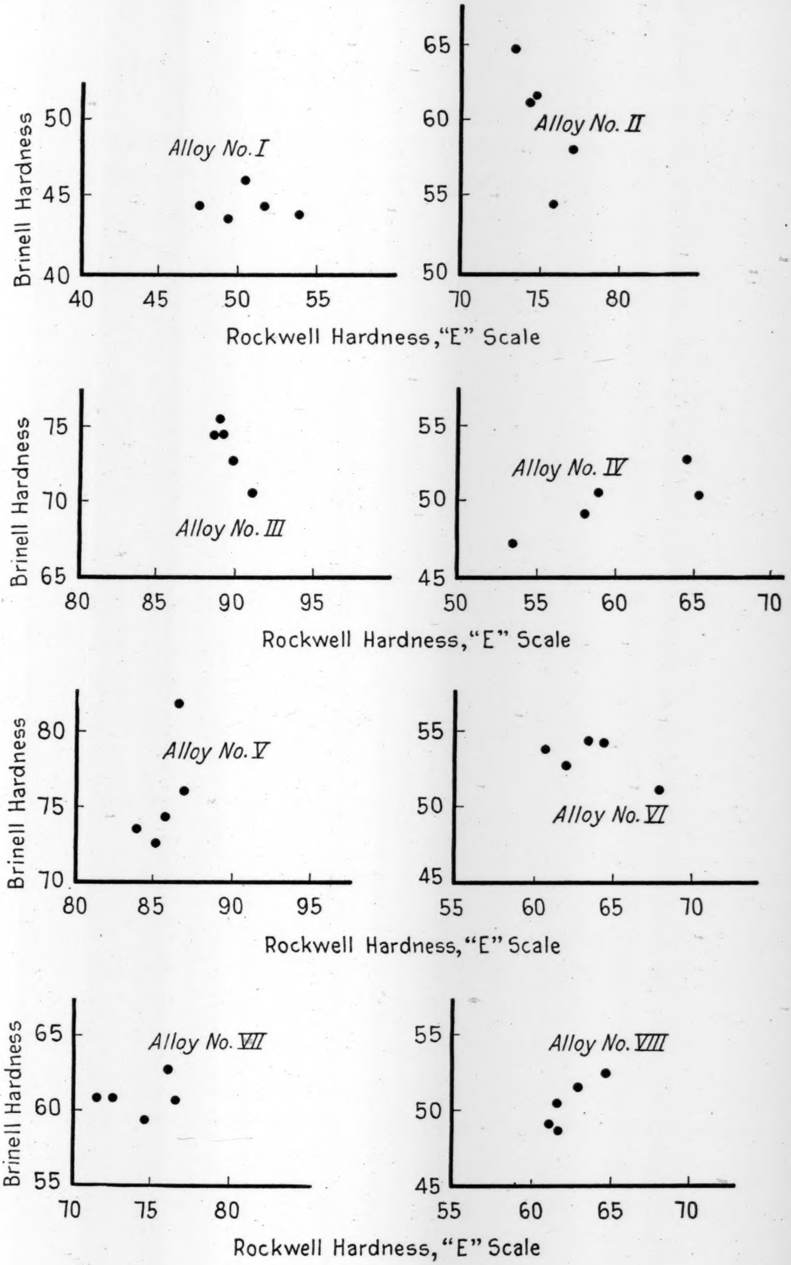

FIG. 12.—Correlation of Brinell Hardness Numbers with Rockwell Hardness, "E" Scale, of Aluminum-Base Die-Casting Alloys. Specimens from Producer A, Results by Laboratory N.

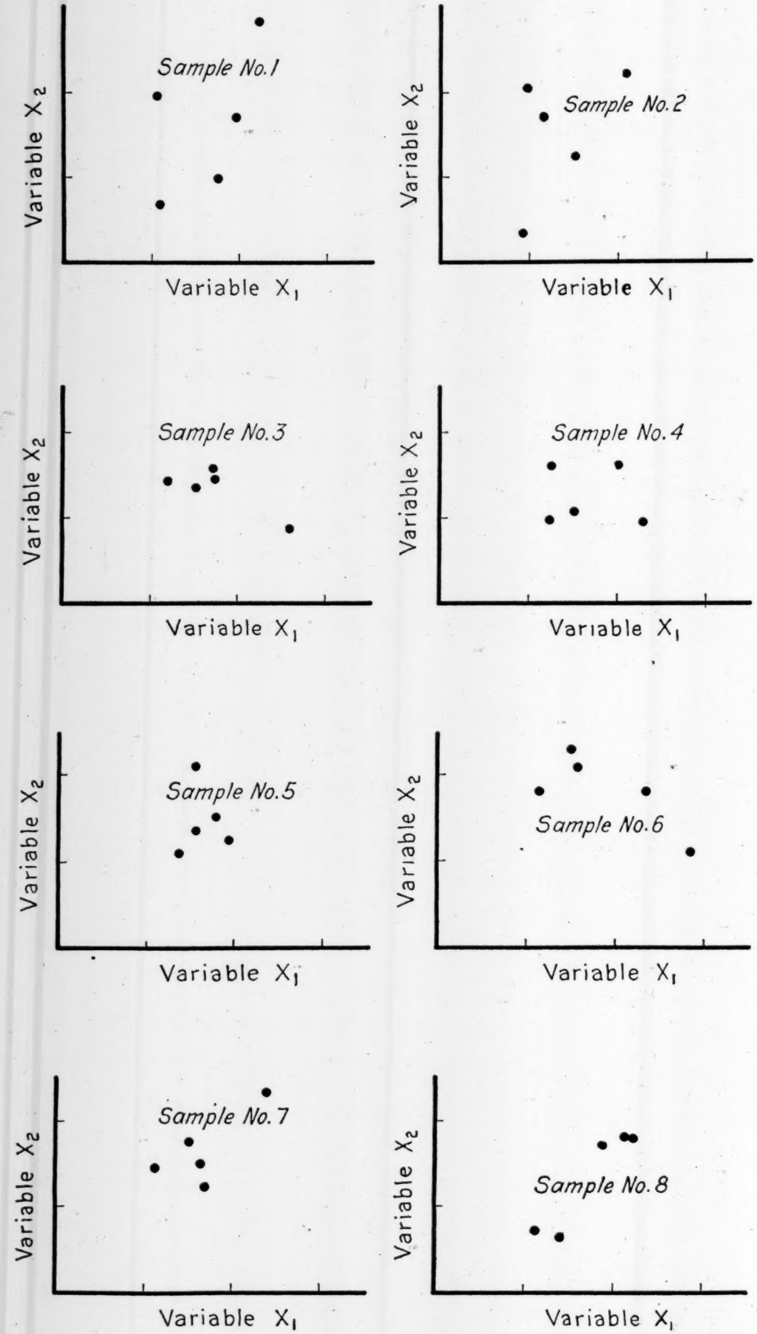

FIG. 13.—Typical Results Obtained from Uncorrelated Variables X_1 and X_2 Illustrating Lack of Assignable Correlation Shown by Figs. 10 and 11.

studies were made by W. A. Shewhart and F. W. Winters and they suggest that the existence of a relationship between these variables may perhaps be established when a sufficiently large number of hardness measurements are made to reduce the experimental error in the hardness determination to an amount consistent with the error involved in the tensile strength determinations. The methods used in such studies are described briefly in Appendix I to the 1929 Report.[1]

In addition to the charts based on these statistical studies of the aluminum alloys, data are given in Tables I to III for various tests on the zinc-base alloys, analyses of these alloys as made by two cooperating laboratories and the metallographic report on the zinc-base alloys. A photograph showing the condition of the various zinc-base alloys after exposure in water vapor at 95° C. will be found in Mr. Colwell's paper.[2]

Respectfully submitted on behalf of the subcommittee,

H. A. ANDERSON,
Chairman.

P. V. FARAGHER,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 200 (1929).

[2] *Loc. cit.*

APPENDIX I

METALLOGRAPHY OF ZINC-BASE DIE-CASTING ALLOYS

By W. M. Peirce[1]

This discussion deals entirely with the alloys containing several per cent of aluminum and of copper, such as the 4 per cent aluminum - 3 per cent copper alloy and the 4 per cent aluminum - 3 per cent copper - 0.1 per cent magnesium alloy. Any consideration of the metallography of these alloys must be based on a study of the binary system zinc aluminum.

The Zinc Aluminum Alloy System.—Somewhat less than 1 per cent of aluminum enters into solid solution with zinc to form a homogeneous alloy consisting of a single phase known as the alpha phase. Zinc added to aluminum in amounts up to the neighborhood of 20 per cent enters into solid solution to form a homogeneous alloy consisting of a gamma phase. Zinc aluminum alloys containing from 1 to 21 per cent aluminum, between the freezing point and about 270° C., consist of a eutectic of alpha and a new phase or constituent known as beta together with an excess of alpha, if the aluminum content is less than 5 per cent, or of beta, if the aluminum content is above 5 per cent.

At a temperature of about 270° C. this beta constituent is transformed into a mixture of alpha and gamma. This transformation is accompanied by a decrease in volume and an evolution of heat. In the pure zinc-aluminum alloys, the transformation is extremely rapid. Certain elements, notably copper, magnesium, and nickel, which may be added to these alloys, have a very pronounced effect on the rate of transformation and hence on the resulting properties of the alloys. The presence of 3 per cent of copper in an alloy containing 4 per cent of aluminum prevents the transformation from occurring immediately in chill-cast alloys. The transformation, however, does occur slowly at room temperature, perhaps requiring several years to become complete. The addition of magnesium and nickel, either separately or together, further affect the rate in an advantageous manner, as judged by the properties of the alloys.

Heat Treatment of Zinc-Base Die-Casting Alloys.—As stated above the transformation of beta into alpha and gamma is enormously retarded in chill-cast alloys by the presence of copper and other elements in addition to aluminum; in other words, finished die castings of these alloys contain beta which in the course of a few years at ordinary atmospheric temperatures or in the course of a few days at 100° C. or of even shorter periods at higher temperatures is converted into alpha and gamma. This change is accompanied by a slight change in dimensions. The physical properties also undergo some change in the direction of a small decrease in tensile strength and a decrease in impact strength. That these changes are due to the reversible beta transformation and not to corrosion of any character is evidenced by the fact that the original properties of aged specimens may be restored by reheating to above the transformation temperature and cooling rapidly.

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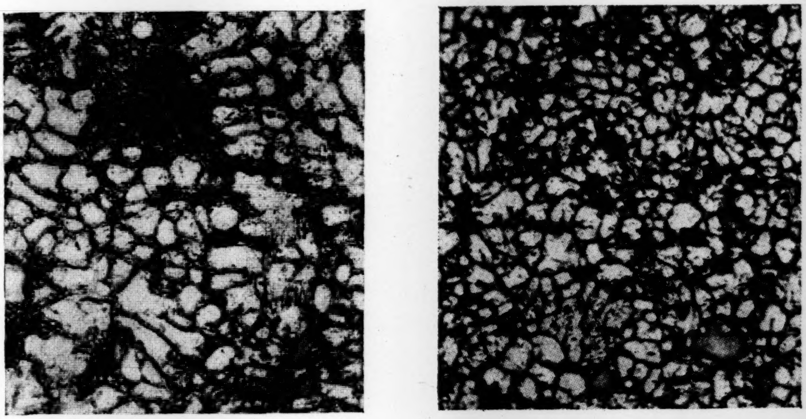
[1] Chief of Metal Research Division, New Jersey Zinc Co., Palmerton, Pa.

These facts suggest the possibility of heat treating these alloys to bring about the beta transformation with its accompanying dimensional change before the castings are put into use. There is another factor, however, that has a bearing on this matter. As in other alloys which owe their properties to a highly dispersed phase, the properties are influenced by the size of the dispersed particles and this size depends possibly on the rate at which the particles have been precipitated and certainly upon the length of time that the alloy has been exposed to a temperature where growth of the particles can occur. Therefore, rapid artificial aging treatments, which complete the beta transformation, may not yield the same final properties as aging at room temperature. Work along this line has been started by one of the groups of Subcommittee XV on Die-Cast Metals and Alloys.



(*a*) Specimen of 4-per-cent aluminum, 3-per-cent copper, 0.1-per-cent magnesium alloy, die cast in a hot die. The white constituent is alpha, a solid solution of copper and aluminum in zinc.

(*b*) Specimen of 4-per-cent aluminum, 3-per-cent copper, 0.1-per-cent magnesium alloy, die cast in a cool die. Gray constituent probably a copper-rich phase.

FIG. 1.—Typical Photomicrograph of Two Zinc-Base Die-Casting Alloys (× 500). Etching Reagent 20 g. Cr_2O_3, 3 g. Na_2SO_4 and 100 cc. H_2O.

The matrix is a eutectic of alpha (light) and beta, a zinc-aluminum compound or solid solution (dark). It is the transformation of this dark constituent to alpha and gamma which principally accounts for aging changes.

Microscopy.—The microscopic study of the structure of these alloys has not furnished information of especial value, since the important questions relate to the structure of the mixture of alpha and gamma resulting from the transformation of beta and this structure has proved too fine to resolve by the usual microscopic methods.

The microstructure can, of course, yield some information as to the degree of chilling and hence offers a check on the casting conditions. Beyond this, microscopic examination of the alloys does not appear to be of great value as a control method. Two typical photo-micrographs are shown in Fig. 1 as a matter of general interest.

APPENDIX II

A LIST OF ALLOYS

BY WILLIAM CAMPBELL[1]

In connection with the activities in the nomenclature of non-ferrous metals and alloys of Committee B-2 on Non-Ferrous Metals and Alloys, in order to show the difficulties which are met with when an attempt is made to formulate a logical and scientific classification of alloys, the following list of alloys has been compiled.

The subject of nomenclature is one of some difficulty. Brass has been defined as an alloy of copper with zinc as the principal alloying metal, whereas bronze is a copper alloy in which tin is the chief added element, and yet it is the custom to call red brass by the name of "bronze." Again, Tobin "bronze," manganese "bronze," etc., are, properly speaking, brasses.

While this list is primarily one of non-ferrous alloys, there have been added a few examples of what are, properly speaking, iron alloys (in contra-distinction to steel) in which the properties are dependent on the added elements, as, for example, in the list of non-corrosive alloys and of the heat-resisting alloys as well as those used for resistance purposes.

It often happens that when a new alloy is brought out its composition is apparently new, but on referring to some of the older books on metals and alloys we find it mentioned under another name. Numerous alloys can be found in such works as Bischoff (1865), Berlin; Bolley (1869), Paris; Guettier (Fesquet); Thurston (Part 3); Law's "Alloys"; R. A. Wood's "The Waterbury Book of Alloys," etc.

In 1911, Kaiser published a very complete list of metals and alloys in *Metallurgie* (1911), Vol. VIII, pp. 257, 296.

In 1918, the *Metal Industry* of London published a small booklet entitled "Metals and Alloys" which covered Kaiser's list with some few additions.

While both of these lists are useful in that they are arranged alphabetically, for our purpose an arrangement by groups is better in that it shows the wide variations in composition in many of our commercial alloys. In the accompanying list, therefore, this method has been followed, using Kaiser's list as a basis and adding to it such other alloys as have been found in the literature or met with in practice. The arrangement of groups is as indicated below, the page number on which each group may be found being included for easy reference:

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[1] Howe Professor of Metallurgy, School of Mines, Columbia University, New York City; Chairman of Committee B-2.

PAGE

Brasses.......... 339
Bronzes.......... 349
Copper-Nickel Alloys.......... 357
Copper-Nickel-Zinc Alloys (Nickel Silver, Agiroide, Alfenide, Argentan, Arguzoid, Argyrolith, Electrum, Neusilber, Nickelin, Maillechort, Paktong, Sterlin, Tutenag, White Copper, etc.).......... 359
Aluminum Bronzes, etc.......... 363
Copper-Manganese Alloys.......... 365
Copper-Silicon Alloys.......... 366
Aluminum Alloys.......... 367
Magnesium Alloys.......... 376
Tin Base Alloys.......... 377
Lead Base Alloys.......... 380
Zinc Base Alloys.......... 383
Fusible Metals.......... 384
Gold Alloys.......... 385
Silver Alloys.......... 387
Platinum, etc.......... 388
Resistance Alloys.......... 389
Heat Resisting Alloys.......... 391
Corrosion-Resisting Alloys.......... 392
Stainless and Corrosion-Resisting Alloys.......... 393
Cobalt Alloys.......... 395
Hard Alloys, Tools, Dies, etc.......... 396
Pyrophoric Alloys.......... 396

It is realized that this list is incomplete and additions or corrections will be very welcome.

June, 1922.

During the past eight years a number of new alloys have made their appearance and the first edition having become exhausted, the Advisory Committee decided that the List of Alloys ought to be brought up-to-date and that a few examples of typical physical properties might be incorporated.

In this revision several members of Committee B-2 have given a great deal of help, especially W. H. Bassett, R. H. Leach and E. E. Thum. The Aluminum Company of America, the Bell Telephone Laboratories, Inc., and others have also contributed, and I wish to record my indebtedness to all this help. My thanks are also extended to Mr. V. Scalise, assistant in metallurgy, Columbia University, for untiring assistance during this revision.

The grouping of Resistance, Heat-Resisting, Stainless and Corrosion-Resisting Alloys is perhaps open to criticism because numerous alloys fall under more than one division, yet to group them all together is cumbersome and it seemed better to retain the original classification. For the group formerly called Nickel Silver or German Silver a new name is still being sought, Cunizin and Nicuzin being too synthetic and nickel-brass being anathema to some of our practical friends.

WM. CAMPBELL.

June, 1930.

BRASSES

	Cu	Zn	Sn	Pb	Fe	Other Elements and Comments
Abyssinian Gold	88.	11.5	....	....	....	Au, 0.5
Admiralty, A (tubes)	70.	29.	1.	....	....	
Aitch Metal	60.	38.2	....	....	1.5	
Alumbro (tubes)	76.	22.	....	....	....	Al, 2
Aluminum Brass	63.	33.3	....	....	....	Al, 3.3; Si, 0.3
Anvil Brass	62.50	37.50	....	....	....	
Arko	80.	20.	....	....	....	
Augsburg	71.9	27.6	....	0.85	....	
Austrian Journal Box	92.5	7.5	....	....	....	
Barronia (tubes)	83.	Bal.	2.	0.5	....	
Bath Metal	55.	45.	....	....	....	
Bath Metal	83.	17.	....	....	....	
Battery Copper	94.00	6.00	....	....	....	
Bell Brass	64.25	35.00	0.75	....	....	
Belt Lace	62.00	38.00	....	....	....	
Best Bronze	90.00	10.00	....	....	....	
Binding Brass	63.25	35.00	....	1.75	....	
Birmingham Platina	46.6	53.15	....	....	0.25	
Bismuth Brass	47.	21.	1.	....	....	Ni, 30.9; Bi, 0.1
Blatt Gold	77.	23.	....	....	....	
Block Brass	66.50	32.00	....	1.50	....	
Bobierre Metal	66.	34.	....	....	....	
Bobierre Metal	58.2	41.7	....	....	....	
Bow Wire	93.00	2.00	5.00	....	....	
Brazing Metal, F	85.	15.	....	....	....	
Brazing Brass	75.00	25.00	....	....	....	
Bridgeport Bronze	60.	Bal.	0.75	....	....	
Bright Cap Gilding	89.75	9.87	....	0.38	....	
Bristol	75.7	24.3	....	....	....	
Bristol	67.2	32.8	....	....	....	
Bristol	60.8	39.2	....	....	....	
Bronze Powder	84.0	16.0	....	....	....	
Brush Wire	64.25	35.	0.75	....	....	
Buckle Brass	65.00	35.	....	....	....	
Bullet Brass	90.	9.	....	1.	....	
Burr Brass	62.00	38.00	....	....	....	
Burr Metal	90.00	10.00	....	....	....	
Butt Brass	65.50	33.50	....	1.	....	
Butt Brass	63.50	35.50	....	1.	....	
Button Brass	89.50	10.00	0.50	....	....	
Button Metal	43.	57.	....	....	....	
Button Metal, Ludensheidt	20.	80.	....	....	....	
Buttons (Thurston):						
Bristol Alloy	57.9	36.8	5.3	....	....	
Bristol Alloy	61.12	36.11	2.77	....	....	
Jackson's Alloy	63.88	30.55	5.55	....	....	
Jackson's Alloy	63.01	35.61	1.39	....	....	
"Bidery"	48.50	33.32	6.06	12.15	....	
"Gold"	58.71	33.03	5.50	2.75	....	
Cap Gilding	90.00	10.00	....	....	....	
Cartridge Brass	66.67	33.33	....	....	....	
Cartridge Brass	68.00	32.00	....	....	....	
Cartridge Brass	70.00	30.00	....	....	....	
Cartridge Gilding	93.00	7.00	....	....	....	
Cazin (Solder for Steel)	82.6	17.4	....	....	....	
Chamet Bronze	60.	39.25	0.75	....	....	
Check Brass	62.	38.	....	....	....	

BRASSES (*Continued*)

	Cu	Zn	Sn	Pb	Fe	Other Elements and Comments
Chrysokalk	90.5	7.9	....	1.6	....	
Chrysokalk	58.7	40.2	....	1.1	....	
Chrysorin	72.	28.	....	....	....	
Chrysorin	66.7	33.3	....	....	....	
Chrysorin	63.3	36.7	....	....	....	
Clinching Screw Wire	69.	29.50	....	1.50	....	
Clock Brass	62.50	35.75	....	1.75	....	
Collet Brass	61.00	36.50	....	2.50	....	
Commercial Brass, B-r	63.	37.	....	....	....	
Commercial Bronze	90.00	10.00	....	....	....	
Commercial Castings, B-c	62.	30.	6.	2.	....	
Common Brass	65.	35.	....	....	....	
Corronium, cast or wrought	80.	15.	5.	....	....	
Cuivre Poli	70.	30.	....	....	....	
Cymbal Metal	78.	22.	....	....	....	
Delatot's Metal	80.	18.	....	....	....	Mn, 2.0
Delta-Bronze	54–56	Bal.	....	1–2	1.	Mn, 1–3
Delta Krupp	55.94	41.61	....	0.72	0.87	Mn, 0. 81; P, 0.013
Delta Krupp	55.8	40.07	....	1.82	1.28	Mn, 0.96
Delta Krupp	55.82	41.41	....	0.76	0.86	Mn, 1.38
Delta Krupp	54.22	42.25	....	1.10	0.99	Mn, 1.09
Delta Metal	55.1	43.5	....	0.37	1.08	P, 0.1
Delta Metal	58.3	39.	....	0.15	0.13	Ni, 2.2
Diaphragm Brass	95.00	2.00	3.	....	....	
Dipping Brass	66.66	33.34	....	....	....	
Door Plate Brass	65.	35.	....	....	....	
Door Plate Brass	63.	35.	....	2.00	....	
Doctor Metal	88.	9.50	2.50	....	....	
Drawing Brass, Deep	70.	30.	....	....	....	
Drawing Brass	66.67	33.33	....	....	....	
Drill Rod	62.	35.50	....	2.50	....	
Durana	65.	30.	2.	....	1.5	Al, 1.5
Dutch Metal	76.	24.	....	....	....	
Eisen Bronze	57.5	39.5	1.	0.3	1.3	Al, 0.3
Electrical Brass Castings, B. E	84.	13.	3.	....	....	
English	70.3	29.3	0.17	0.26	....	
Engravers' Brass	66.	33.	....	1.00	....	
Escutcheon Pin Brass	64.50	35.07	....	0.43	....	
Eugene Vaders	57.5	Bal.	....	....	0.3	Mn, 2.5; Al, 1.5; Si, 0.5
Eyelet Brass	68.	32.	....	....	....	
Eyelet Brass	65.	35.	....	....	....	
Fan Blades	61.50	37.00	....	1.50	....	
Flush Plate	65.75	32.75	....	1.50	....	
Fob Metal	87.50	12.00	0.50	....	....	
Forbes Metal (Button)	46.5	53.5	....	....	....	
Forgings	60.	40.	....	....	....	
Forgings	57.	43.	....	....	....	
Forgings, Russian	53.5	42.	....	....	....	Mn, 4.5
Fourdrinier Wire	84.63	15.	0.37	....	....	
Fourdrinier Wire	80.	20.	....	....	....	
Free Cutting Bronze	88.50	10.00	....	1.50	....	
Gedges Metal	60.	38.5	....	....	1.5	
Gold Leaf Metal	84.	16.	....	....	....	
Gold Leaf	66–80	34–20	....	....	....	
Gold Leaf, Jemmapes	64.6	33.7	1.4	0.2	....	
Gold Leaf, Aix	64.8	32.8	2.0	0.4	....	
Gong Metal	78.	22.	....	....	....	
Grommet Brass	70.	30.	....	....	....	
Guettier's Button	56.	44.	....	....	....	
Guettier's Button	61.5	32.	6.5	....	....	

BRASSES (*Continued*)

	CU	ZN	SN	PB	FE	OTHER ELEMENTS AND COMMENTS
Guettier's Button	61.4	28.9	9.7	....	....	
Guinea Gold	88..	12.	....	....	....	
Halberland Alloy	87.	13.	....	....	....	
Hamilton Metal	66.7	33.3	....	....	....	
Hardware Bronze	88.	12.	....	....	....	
Hardware Bronze	88.	9.50	1.50	1.00	....	
Harlington Bronze	55.7	42.7	0.97	....	0.58	
Harmonia Bronze	57.	40.	....	0.4	1.8	
Harmonia Bronze	55.7	41.2	0.5	0.46	1.29	Al, 0.86
Helmet Bronze	70.	30.	....	....	....	
Helmet Metal	72.27	27.58	....	....	....	
Hercules Metal	54.	36.	....	....	7.5	Al, 2.5
High Strength	Bal.	18.5–21.5	....	....	2–3	Al, 6–7; Ni, 1.5–2.25
Hooker Brass	61.	37.	....	2.00	....	
Hy-Ten-Sil Mn Bronze	67.6	22.4	....	....	2.	Mn, 3.2 Al, 4.7
Hydraulic Bronze	83.	5.	5.	5.	....	Ni, 2
Immadium	55–56	42–41	0.9–1.	0.1–0.2	1.5	Al, 0.3
Immadium Rolled, II	60.	35.	....	1.2	1.	Al, 2.6; Mn, 0.3
Immadium Rolled, V	67.8	24.3	....	0.7	1.4	Al, 5.4; Mn, 0.3
Iserlohn, Cast	63.7	33.5	2.5	0.3	....	
Jewelers Metal	91.50	6.50	2.00	....	....	
Jewelers Metal	90.	10.	....	....	....	
Jewlers Metal	83.	17.	....	....	....	
Jewelers Metal	88.	11.25	0.75	....	....	
Jewelers Metal	87.50	12.	0.50	....	....	
Jewelers Metal	91.	7.50	1.50	....	....	
Kick Plate Brass	84.	15.	....	1.00	....	
Kinghorn Metal	58.5	39.3	0.96	....	1.14	
Lancashire Brass	73.	25.	....	2.00	....	
Laveyssiére Bronze	61.	38.	1.	....	....	
Leaded Bronze	88.50	10.00	....	1.50	....	
Leaded Chamet Bronze	60.	38.5	0.75	0.75	....	
Low Brass	80.00	20.00	....	....	....	
Machinery Brass	83.	16.	1.	....	....	
Mallet Alloy	25.4	74.6	....	....	....	
Manganese Brass	69.5	29.5	....	....	....	Mn, 1.0
Manganese Brass	60.15	34.76	0.94	0.39	1.19	Mn, 2.34; Al, 0.2
Manganese Brass	55.4	39.96	....	....	1.6	Mn, 3.20; Al, 0.2
Manganese Brass	55.0	39.5	....	....	0.7	Mn, 4.3; Al, 0.5
Manganese Brass	54.2	38.2	....	....	2.4	Mn, 4.4; Ni, 0.5
Manganese Brass	85.	2.0	....	....	1.83	Mn, 10.91
Manganese Brass	80.	5.	....	....	....	Mn, 15.
Manganese Brass	75.5	8.	....	....	....	Mn, 16.5
Manganese Brass	60.	15.	....	....	....	Mn, 25.
Mn Ni Brass	65.	5.	....	....	....	Mn, 20.; Ni, 10
Mn Ni Brass	59.	20.	....	....	....	Mn, 3; Ni, 18
Mn Ni Brass	63.5	28.28	1.22	0.17	1.44	Mn, 3.24; Ni, 2.14
Mn Ni Brass	51.15	40.	....	....	2.25	Mn, 4.15; Ni, 2.2; Al, 0.25
Mn Ni Brass	53.5	39.	.07	....	2.78	Mn, 1.52; Ni, 2.35
Mn-Bronze	55–60	39–45	2.	....	2.	Al, 0.5
Mn-Bronze, Rolled	59.	39.7	1.	....	....	Mn, 0.3
Mn-Bronze, Cast	58.	40.	....	....	....	Mn, 2.
Manganin	53.4	39.	2.66	....	....	Ni, 2.5; Mn, 1.7; Al, 0.2
Manheim Gold	89.4	9.92	0.62	....	....	
Manheim Gold	83.7	9.3	7.	....	....	+ 5 per cent of Phos. Tin
Manheim Gold	88.	12.	....	....	....	
Manheim Gold	80.	20.	....	....	....	
Market Brass	65.	35.	....	....	....	
Matrix Brass	62.	36.50	....	1.50	....	
McKechnie's	57.	41.	1.	0.5	1.	

BRASSES (*Continued*)

	CU	ZN	SN	PB	FE	OTHER ELEMENTS AND COMMENTS
Medal Metal	84.00	16.00	....	....	....	
Mosaic Gold	63.	35.	....	....	....	
Mueller Blue Tip Bronze	60.36	38.6	0.94	....	....	
Muntz Metal	60.	40.	....	....	....	
Naval Brass, N-c	61.	38.	1.	....	....	
Nergaudin (tubes)	70.	28.	....	2.	....	
Neustadt, Drawn	71.5	28.5	....	....	....	
Nickel Brass	54.1	43.66	....	....	0.5	Ni, 1.5
Non-Tarnishable	63.6	31.	3.25	2.	....	
Nu-Gold	87.73	12.22	....	....	....	
Oker, Cast	71.9	24.4	....	1.1	2.32	
Oker Brass (Harz)	64.24	37.27	0.59	0.12	....	
One Ton Brass	61.	38.	1.	....	....	
Optical Bronze	89.00	6.50	4.50	....	....	
Oreide	87.25	11.50	1.25	....	....	
Oreide	90.	10.	....	....	....	
Oreide	85.5	14.5	....	....	....	
Oreide	80.5	14.5	4.85	0.1	....	
Oreide, Brunswick	68.21	31.52	0.48	....	....	
Parson's Mn Bronze	60.15	34.76	0.94	0.39	1.19	Mn, 2.34; Al, 0.23
Parson's No. 1	57–58	Bal.	0.5	....	1.	Mn, 1; Al, 1; Ni, 0.2
Pen Metal	85.00	13.00	2.00	....	....	
Percussion Cap	95.00	5.00	....	....	....	
Pewter (Thurston):						
Berthier's Alloy	71.9	24.9	1.2	2.0	....	
Cast and worked	64.2	34.6	0.2	2.0	....	
Cast and worked	61.6	35.3	0.6	2.5	....	
Cast gilt	63.7	33.5	2.5	0.3	....	
Cast gilt	64.5	32.4	0.2	2.9	....	
For clock work	60.66	36.88	1.35	0.74	....	
For clock work	66.06	31.46	1.43	0.88	....	
Pinchbeck	93.6	6.4	....	....	....	
Pinchbeck	88.8	11.2	....	....	....	
Pinchbeck	83.33	16.76	....	....	....	
Pinkus Brass	88.1	6.9	2.5	1.8	....	Ni, 0.3; Sb, 0.32
Pin Wire	61.00	39.00	....	....	....	
Piston	83.	16.	1.	....	....	
Platine	43.	57.	....	....	....	
Potinjaune	71.9	24.9	1.2	2.0	....	
Primer Gilding	97.00	3.00	....	....	....	
Prince's Metal	83.	17.	....	....	....	
Prince's Metal	75.	25.	....	....	....	
Prince's Metal	60.8	39.2	....	....	....	
Promethium	67.	30.	....	....	....	Al, 2.5–3
Reed Brass	69.00	30.00	1.00	....	....	
Rich Gold Metal	90.00	10.00	....	....	....	
Rich Low Brass	85.00	15.00	....	....	....	
Roman Bronze	58–60	Bal.	1.	....	1.	Al, 1.10; Mn, 0–2.0
Rubel Bronze	55.5–57	39–40	....	....	1.5–2	Ni, 1–3; Al, 0.5
Rubel Bronze H1	41.	48.	....	....	....	11 per cent of Al-Fe-Mn-Ni
Rubel Bronze W1	50.	41.	....	....	....	9 per cent of Al-Fe-Mn-Ni
Rubel Metal	55.	40.	....	....	....	5 per cent of Al-Fe-Mn-Ni
Rubel Metal	51.	40.	....	....	....	5 per cent of Al-Fe-Mn-Ni Alloy and 4 per cent of Ferro Mn
Rule Brass	62.50	35.00	....	2.50	....	
Russian, Cast	78.	21.	1.	....	....	
Russian, Cast	70.	30.	....	....	....	
Russian, Cast	66.6	33.4	....	....	....	
Scovill Hardware Bronze	89.	Bal.	....	2.	....	Ni, 1

BRASSES (*Continued*)

	Cu	Zn	Sn	Pb	Fe	Other Elements and Comments
Screen Plates	58.00	41.00	0.75	0.25	....	
Screw Bronze	93.50	5.00	1.00	0.50	....	
Screw Brass	78.	16.	4.5	1.5	....	
Screw Metal	60.	Bal.	....	1.5	....	
Screw Wire	62.00	38.00	....	....	....	
Seamless Tubing	60.00	40.	....	....	....	
Seamless Tubing	61.50	38.50	....	....	....	
Sheet:						
Stollberg	64.8	32.8	0.4	2.0	....	
Jamappes	64.6	33.7	0.2	1.4	....	
Rosthorn-Wiln	68.1	31.9	....	....	....	
Oker I	69.	29.5	....	0.97	....	
Oker	55.	44.5	0.5	....	....	
Iserlohn	70.1	29.9	....	....	....	
Romilly	70.1	29.26	0.17	0.28	....	
China	56.6	38.2	3.3	1.0	1.40	
Japan	66.6	33.4	....	....	....	
Hegermuhl	72.16	27.45	0.2	0.79	....	
Hegermuhl	72.	27.	1.	....	....	
Hegermuhl	62.	37.	0.5	0.5	....	
Hegermuhl	62.	37.	1.	....	....	
Shell Head Brass	75.00	25.00	....	....	....	
Shoe Nail Brass	63.00	37.00	....	....	....	
Shoe Tip Metal	88.00	12.00	....	....	....	
Similor	89.4	9.93	0.6	....	....	
Similor	83.7	9.3	7.0	....	....	
Similor	80.	20.	....	....	....	
No. 600 Bearing Metal	59.7	35.	0.2	0.33	....	Mn, 2.6; Al, 1.38: Si, 0.7
Solder, Hard	57.	43.	....	....	....	
Solder, Hard	50.	50.	....	....	....	
Solder, White	40.	60.	....	....	....	
Solder (Thurston):						
Yellow, Hard	53.30	43.10	1.30	0.30	....	
Nearly White, Soft	44.	49.90	3.30	1.20	....	
White, Very Soft	57.44	27.98	14.58	....	....	
Spring Brass	72.00	28.00	....	....	....	
Spring Brass	66.67	33.33	....	....	....	
Statuary (see Statuary Bronzes)						
Steel Bronze, cast or forged	52–59	36–43	....	....	1.	Mn, 2.5–3; Al, 1
Sterro Metal	60.	38.2	....	....	1.8	
Sterro Metal	55.	42.4	0.83	....	1.8	
Sterro Metal	55.5	42.	....	....	2.5	
Sterro Metal	55.3	41.8	....	....	4.66	
Sterling	66.2	33.1	....	....	0.7	
Sterling, Cast	66.2	33.11	....	0.02	0.66	
Super Mn-Bronze	69.	20.	....	....	....	Al, 6.5; Fe, 2.5; Mn, 2. Tens. Str., 110,000 lb. per sq. in.; Elongation, 10 per cent in 2 in.
Superbronze	56.8	37.5	....	....	1.3	Mn., 3.2; Al, 1.2
Superbronze	68.9	20.9	....	....	2.0	Mn, 3; Al, 5.1
Talmi Gold	90.	8.92	....	....	....	Au, 0.91
Talmi Gold	86.4	12.2	1.1	....	0.3	
Tensilite	64.	29.	0.2	....	1.2	Mn, 2.5; Al, 3.1
Tensilite	67.	24.	....	....	....	Mn, 3.8; Al, 4.4
Thurston's	55.	44.5	0.5	....	....	
Tissier's	97.	2.0	0.5	....	....	
Tissier's	97.	2.0	....	....	....	As, 1.0
Tobin Bronze, 1875	58.2	39.5	2.3	....	....	

BRASSES (*Continued*)

	Cu	Zn	Sn	Pb	Fe	Other Elements and Comments
Tobin Bronze, cast	60.	38.	2.	....	....	
Tobin Bronze, rolled	60.	39.25	0.75	....	....	
Tombac:						
Oker	85.3	14.7	....	....	....	
Arcet	82.3	17.7	....	....	....	
Ludenscheidt	82.3	17.5	....	....	....	
Red Vienna	97.8	2.2	....	....	....	
Sheet, Paris	92.	8.	....	....	....	
Sheet, Paris	88.	12.	....	....	....	
Sheet, Paris	84.	16.	....	....	....	
Golden	82.	17.5	0.5	....	....	
French	80.	17.	3.	....	....	
French	80.	20.	....	....	....	
Cast	87.	13.	....	....	....	
Common	71.5	28.5	....	....	....	
Tournay's	82.54	17.46	....	....	....	
Tubes, etc.:						
German	70.	30.	....	....	....	
German	60.	40.	....	....	....	
Russian	66.	34.	....	....	....	
Russian	59.72	38.62	0.16	0.34	1.1	
English	65.	35.	....	....	....	
Admiralty	70.	29.	1.0	....	....	
Turbadium	50.94	43.	0.5	0.3	1.36	Mn, 2.2; Ni, 1.75
Turbadium	48.	46.5	0.5	0.1	1.0	Mn, 1.75; Ni, 2
Turbiston's	55.	41.	....	....	0.84	Ni, 2; Al, 1.0; Mn, 0.16
Tungsten Brass	59.73	33.97	0.15	....	....	Al, 2.8; W, 2.; Mn, 0.7 (Ni, 0.75)
Turbine Brass	75.77	24.07	....	....	....	
Turbine Brass	67.35	32.02	....	0.23	0.38	
Vanadium Bronze Vn-c	61.	38.5	....	....	....	Va, 0.5
Vanadium Brass	70.	29.5	....	....	....	Va, 0.5
Washer Brass	62.00	38.00	....	....	....	
Weatherstrip Bronze	89.	9.5	1.5	....	....	
Wheel Brass	68.00	30.00	....	2.00	....	
White Bronze	53.7	42.	....	....	....	Ni, 4; Fe + Al, 0.3
Wiegold (Dental)	67–68	33–32	....	....	....	Al, 0.28
Winn's Superheat	62.1	35.	2.	0.4	....	As, 0.13; Fe, 0.2
Wire	70.29	29.26	0.17	0.28	....	
Wire, English	70.29	29.36	0.28	0.17	....	
Wire, Augsburg	71.89	27.33	....	0.85	....	
Wire, Common	65.4	34.6	....	....	....	
Yale Bronze	Bal.	7.5–8	0.5–1.5	0.7–1.5	....	

PHYSICAL PROPERTIES OF ALLOYS FROM A.S.T.M. SPECIFICATIONS FOR BRASSES

B 54 – 27. Manganese Bronze Sand Castings.
Cu, 60–65; Zn, 42–38; Sn, 0–1.5; Mn, 0–3.5; Al, 0–1.5; Fe, 0–2; Pb, 0–0.4.
Tens. Str., 65,000 lb. per sq. in.; Elongation in 2 in., 25 per cent.

B 65 – 28. Yellow Brass Sand Castings.
Cu, 62–67; Pb, 1.5–3.5; Sn, 1 max.; Fe, 0.75 max.; Ni, 0.25 max.; Al, 0.3 max.
Tens. Str., 20,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

B 64 – 28. Brazing Solder. (S.A.E. 45.)
50–50 Grade. Cu, 50–53; Pb, 0.5 max.; Fe, 0.1 max.; Zn, Bal. Round grain and long grain.
52–48 grade. Cu, 52–55; Pb, 0.5 max.; Fe, 0.1 max.; Zn, Bal. Round grain and long grain.

B 30 – 30 T. Copper-Base Alloys in Ingot Form for Sand Castings.

ALLOY	COPPER, PER CENT	LEAD, PER CENT	TIN, PER CENT	ZINC, PER CENT	ANTIMONY, PER CENT	IRON, PER CENT	NICKEL, PER CENT	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	REDUCTION OF AREA, PER CENT	BRINELL HARDNESS NUMBER (500 KG. FOR 30 SEC.)
No. 1.	Bal.	1.50 to 2.50	9 to 11	1.50 to 2.50	0.25	0.25	0.50	32 000 to 38 000	15 to 20	15 to 20	55 to 65
No. 2.	Bal.	1.50 to 2.50	7.25 to 8.75	3.50 to 4.50	0.25	0.25	0.50	30 000 to 36 000	25 to 30	25 to 30	55 to 65
No. 3.	Bal.	4.25 to 5.75	5.25 to 6.75	2.50 to 3.50	0.25	0.25	0.50	25 000 to 33 000	15 to 20	15 to 20	45 to 60
No. 4.	Bal.	4.25 to 5.75	4.25 to 5.75	4.25 to 5.75	0.25	0.25	0.50	27 000 to 33 000	15 to 20	15 to 20	50 to 60
No. 5.	Bal.	4.25 to 5.75	3.25 to 4.75	9 to 11	0.25	0.35	0.50	29 000 to 35 000	25 to 35	20 to 30	40 to 50
No. 6.	Bal.	7 to 9	2.50 to 3.50	8.50 to 11.50	0.25	0.35	0.50	22 000 to 28 000	10 to 15	10 to 15	50 to 55
No. 7.	Bal.	9 to 11	9 to 11	1.00 max.	1.00	0.25	0.50	27 000 to 33 000	7 to 12	8 to 13	47 to 52
No. 8.	Bal.	9 to 11	9 to 11	2.00 max.	1.00	0.25	0.50	27 000 to 33 000	7 to 10	7 to 12	47 to 52
No. 9.	Bal.	13.50 to 16.50	7 to 9	2.00 max.	1.00	0.25	0.50	25 000 to 30 000	11 to 17	10 to 16	45 to 50
No. 10.	Bal.	18 to 22	5.25 to 6.75	1.50 max.	1.00	0.25	0.50	22 000 to 27 000	10 to 16	7 to 13	42 to 47
No. 11.	Bal.	14 to 20	3.50 to 5.50	4 to 6	1.00	0.25	0.50	25 000 to 30 000	10 to 15	7 to 13	47 to 52
No. 12.	70 to 75	1 to 4	2.00 max.	Bal.	0.10	0.25	0.50	30 000 to 35 000	35 to 45	25 to 35	40 to 50
No. 13.	67 to 70	1 to 4	1.50 max.	Bal.	0.10	0.30	0.50	30 000 to 35 000	25 to 35	20 to 30	40 to 50
No. 14.	64 to 67	1 to 3	1.00 max.	Bal.	0.10	0.35	0.50	30 000 to 35 000	25 to 35	20 to 30	40 to 50
No. 15.	60 min.	3.00 max.	1.00 max.	Bal.	0.10	0.35	0.50	30 000 to 45 000	15 to 25	20 to 30	40 to 50

No. 1. Commercial bronze for general service.
No. 2. High-pressure steam fittings.
No. 3. Steam fittings subjected to moderate pressure.
No. 4. High-grade red brass for general service.
No. 5. Reddish-yellow alloy for air, gas and water fittings.
No. 6. Valve fittings for low pressure.
No. 7. Bearings for heavy pressure (may later be eliminated in favor of Alloy No. 9).
No. 8. Bearings for heavy pressure (lower cost than Alloy No. 7).
No. 9. General service bearings.
No. 10. Bearings operated at high speed and under light or medium pressure.
No. 11. Car journal bearings and similar service.
No. 12. Yellowish red alloy for plumbers' fittings.
No. 13. Yellow brass for light castings and ornamental work not requiring strength or subjected to internal pressure.
No. 14. Yellow brass for heavier castings.
No. 15. Plumbers' flanges, scupper pipes, etc.

B 15 – 18. Brass Forging Rod. (S.A.E. 88.)
Cu, 58.5–61.5; Pb, 1.5–2.5; Fe, 0.15 max. Hot rolled or extruded. Flattens hot 20 per cent.

B 16 – 29. Free Cutting Brass Rod. (S.A.E. 72.)
Cu, 60–63; Pb, 2.5–3.75; Fe, 0.15 max. Cold Bend 120 deg. around 2 diameters.

B 19 – 29. Cartridge Brass.
Cu, 68–71; Pb, 0.07 max.; Fe, 0.05; Other Elements, 0.15. Brinell Hardness No. 49–65.

B 21 – 29. Naval Brass Rods. (S.A.E. 73; Sn, 0.5–1.5.)
Cu, 59–61; Sn, 0.5–1; Pb, 0.3 max.; Fe, 0.1. Cold Bend 120 deg. radius of 1 diameter.

DIAMETER, IN.	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT
Up to 1.......	62 000	31 000	25
1 to $2\frac{1}{2}$........	60 000	30 000	30
$2\frac{1}{2}$ to $3\frac{1}{2}$......	56 000	25 000	35
Over $3\frac{1}{2}$.......	54 000	22 000	40

B 36 – 27. High Sheet Brass. (S.A.E. 70.)
Cu, 64.5–67.5; Pb, 0.3 maximum; Fe, 0.05.

	Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Brinell Hardness Number
A. Hard Brass:			
Quarter Hard	45 000	27.5	75 to 95
Half Hard	52 500	15.	95 to 115
Hard	67 500	5.	130 to 150
Extra Hard	80 000	2.	150 to 170
Spring	87 500	1.	160 to 180
B. Soft Brass:			
Light Anneal	45 000	32.	65 to 75
Drawing Anneal	42 000	38.	55 to 65
Soft Anneal	40 000	42.	47 to 55

PHYSICAL PROPERTIES OF ALLOYS FROM A.S.T.M. SPECIFICATIONS FOR PIPE AND TUBES

B 42 – 24. Copper Pipe. Cu, 99.88.
Less than 2 in. in Outside Diameter; Tens. Str., 40,000 lb. per sq. in.; Elongation in 4 in., 10 per cent.
2 in. in Outside Diameter and over; Annealed; Tens. Str., 30,000 lb. per sq. in.; Elongation in 4 in., 25 per cent; Bend 180 deg.

B 43 – 24. Brass Pipe.
Hot Pierced. Cu, 59–63; Pb, 0.5 max.; Fe, 0.07.
Cold Process. Cu, 65–68; Pb, 0.8; max.; Fe, 0.07.

B 14 – 18. Seamless Brass Boiler Tubes.
Cu, 69 minimum; Pb, 0.5 max.; Fe, 0.1. Pressure 750 lb. per sq. in.

B 44 – 29. Admiralty Condenser Tubes.
Cu, 70 minimum; Sn, 0.9–1.2; Pb, 0.075 max.; Fe, 0.06. Hydrostatic 1000 lb. per sq. in.

B 55 – 25. Seamless 70–30 Condenser Tubes.
Cu, 70 minimum; Pb, 0.075 max.; Fe, 0.06.

B 56 – 25. Seamless Muntz Condenser Tubes.
Cu, 59–63; Pb, 0.3 maximum; Fe, 0.07.

B 57 – 27. Muntz Condenser Tube Plates.
Cu, 58–61; Pb, 0.35–0.9; Fe, 0.15 max.; Sn, 0.25.
Tens. Str., 50,000 lb, per sq. in.; Yield Point, 20,000 lb. per sq. in.; Elongation in 2 in., 35 per cent.

B 13 – 18. Seamless Copper Boiler Tubes.
Arsenical, As, 0.15–0.35. Non-arsenical, Cu, 99.88; Impurities 0.12 max.

B 11 – 18. Copper Plates for Locomotive Fireboxes.
Arsenical, As, 0.25–0.5; Tensile Str., 31,000 lb. per sq. in.; Elongation in 8 in., 35 per cent.
Non-arsenical, Cu, 99.88; Impurities 0.12 maximum; Tens. Str., 30,000 lb. per sq. in.; Elongation in 8 in., 30 per cent.

PHYSICAL PROPERTIES OF ALLOYS FROM U. S. NAVY SPECIFICATIONS FOR BRASSES

Composition B-c, Castings. (46 B 11 d)
Cu, 62–67; Pb, 1.5–3.5; Sn, 1 maximum; Fe, 0.75; Ni, 0.25; Al, 0.3. (A.S.T.M. B 65 – 28.)

Composition B-r. Rods, etc. (47 B 2 e)
Cu, 59–68; Sn, 1.5 maximum; Pb, 3.5; Fe, 0.2. Brinell Hardness, Soft 47–55; Spring, 160–180.

Composition B-e. Castings, Electrical. (46 B 12 b)
Cu, 80–88; Sn, 2 minimum; Pb, 2 maximum; Fe, 0.25.

Composition N-c. Naval Brass, Cast. (46 B 10 d)
Cu, 60–65; Sn, 0.5–1.5; Pb, 0–1; Fe, 0.5 maximum; Al, 0.5.
Tens. Str., 30,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

Composition N-r. Naval Brass, Rolled. (46 B 6 f)
Cu, 59–63; Sn, 0.5–1.5; Pb, 0.2 maximum; Fe, 0.06 up to $\frac{1}{2}$ in diameter;
Tens. Str., 60,000 lb. per sq. in.; Yield Point, 27,000 lb. per sq. in; Elongation in 2 in., 35 per cent; Bend 120 deg.
Over 1 in. in diameter;
Tens. Str., 54,000 lb. per sq. in.; Yield Point, 25,000 lb. per sq. in.; Elongation in 2 in., 40 per cent; Bend 120 deg.

Composition Mn-i. Mn Bronze Ingot. (46 B 16 b)
Cu, 55–60; Zn, 38–42; Mn, 3.5 maximum; Al, 1.5; Sn, 1.5; Fe, 0.4–2.
Tens. Str., 70,000 lb. per sq. in.; Elongation in 2 in., 20 per cent.

Composition Mn-r. Mn Bronze Rods. (46 B 15 b)
Cu, 57–60; Sn, 0.5–1.5; Fe, 0.8–2: Mn, 0.5 maximum; Al, 0.25; Pb, 0.2.

	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. ft.	Elongation in 2 in., per cent	Bend, deg.
Soft..............	55 000	22 000	25	180
Plate, Soft.........	57 000	22 000	20	180
Plate, Hard........	60 000	24 000	18	120
1-in. rod, Hard.....	85 000	60 000	8	90

Composition S-c. Cast Screw Pipe Fittings. (46 B 21 d)
Cu, 78–82; Zn, 10–16; Sn, 4–6; Ni, 0.75 maximum; Fe, 0.35; Sb, 0.25.
Tens. Str.. 28,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

Hydraulic Bronze. (Ounce Metal.) (46 B 23 a) (A.S.T.M. B 62 – 28.)

Ornamental Bronze. (46 B 24 a)
Cu, 81.5; Zn, 10; Sn, 2.5; Pb, 6.
Tens. Str., 25,000 lb. per sq. in.; Elongation in 2 in., 12 per cent.

Composition A. Admiralty. Condenser Tubes. (44 T 7 e)
Cu, 70–72; Sn, 0.9–1.2; Fe, 0.06 max.; Pb, 0.075; Zn, Bal.

Seamless Tubes. (44 T 15) Pressures to 450 lb.
(a) Cu, 83–86; Pb, 0.2 max.; Fe, 0.05;
Tens. Str., 30,000 lb. per sq. in.; Elongation in 8 in., 25 per cent.
(b) Cu, 79–82; Pb, 0.2 max.; Fe, 0.05;
Tens. Str., 30,000 lb. per sq. in.; Elongation in 8 in., 25 per cent.

Seamless Tubes. (44 T 16) Pressures over 450 lb.
Cu, 83–86; Pb, 0.2 maximum; Fe, 0.05;
Tens. Str., 35,000 lb. per sq. in.; Elongation in 8 in., 30 per cent.

Seamless Tubes. (44 P 12)
(a) Cu, 79–86; Pb, 0.2 maximum; Fe, 0.05. (Salt water.)
(b) Cu, 65–68; Pb, 0.8 maximum; Fe, 0.07. (Fresh water.)

Rivet Rods. (43 R 4)
Cu, 59–63; Sn, 0.5–1; Fe, 0.06 maximum; Pb, 0.1.

	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation, per cent	Bend, deg.
Up to $\frac{1}{2}$ in.........	60 000	27 000	35	120
$\frac{1}{2}$ to 1 in..........	58 000	26 000	40	120
Over 1 in..........	54 000	25 000	40	120

Composition F. Brazing Metal. (46 M 4 d) Flanges for copper pipe.
Cu, 83–86; Pb, 0.3; Fe, 0.06; Zn, Bal.; Melting Point, 1830–1870° F.

PHYSICAL PROPERTIES OF MORE COMMON WROUGHT BRASSES AND BRONZES FROM AMERICAN BRASS CO.

		Approximate Composition, per cent		Tensile Strength, lb. per sq. in.		Yield Point, lb. per sq. in.		Elongation in 2 in., per cent		Brinell Hardness	
Material	Form	Cu	Zn	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Copper..................	Sheet	99.9	....	51 000	32 500	50 000	12 000	4.0	37.0	107	32
Copper..................	Rod	99.9	....	50 000	32 000	46 000	17 000	18.0	38.0	...	..
Copper..................	Wire	99.9	....	60 000	38 000	38 000	......	3.0[a]	36.0[a]	...	..
Gilding..................	Sheet	95.0	5.0	55 000	35 000	39 000	......	5.0	38.0	110	43
Commercial Bronze.......	Sheet	90.0	10.0	56 000	37 000	45 000	11 000	4.0	40.0	127	50
Red Brass, 85 per cent....	Sheet	85.0	15.0	75 000	42 000	71 000	18 000	4.0	43.0	135	52
Red Brass, 85 per cent....	Tube	85.0	15.0	68 000	42 000	64 000	19 000	6.0	42.0	...	..
Red Brass, 80 per cent....	Sheet	80.0	20.0	85 000	43 000	......	......	4.0	50.0	150	43
Red Brass, 80 per cent....	Wire	80.0	20.0	125 000	49 000	......	......	2.0[a]	43.0	...	..
Brazing Brass............	Sheet	75.0	25.0	90 000	47 000	......	......	3.5	43.0	157	53
Cartridge Brass...........	Sheet	70.0	30.0	86 000	45 000	......	......	4.0	50.0	157	53

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[a] Elongation in 10 in. for diameter over 0.206 in. and in 50 in. for diameter less than 0.204 in.

Material	Form	Approximate Composition, per cent			Tensile Strength, lb. per sq. in.		Yield Point, lb. per sq. in.		Elongation, in 2 in. per cent		Brinell Hardness	
		Cu	Zn	Pb	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Drawing or Spinning Brass	Sheet	66.67	33.33	.....	91 000	46 000	......	......	2.0	52.0	153	52
Commercial or High Brass	Sheet	65.0	35.0	.....	85 000	45 000	......	......	5.0	60.0	153	52
Commercial or High Brass	Rod	65.0	35.0	.....	70 000	45 000	......	......	15.0	50.0	...	..
Muntz Metal	Sheet	60.0	40.0	.....	80 000	57 000	......	20 000	9.5	48.0	158	80
Clock Brass	Sheet	61.5	37.0	1.5	80 000	45 000	......	......	4.0	40.0	142	54
Forging Brass	Rod	60.0	38.0	2.0	70 000	50 000	31 000	32 000	10.0	45.0	122	82
Turning Rod	Rod	62.0	35.0	3.0	72 000	47 000	60 000	32 000	12.0	60.0	130	54
		Cu	Zn	Sn								
Admiralty	Sheet	70.0	29.0	1.0	95 000	45 000	......	......	5.0	60.0	...	..
Tobin Bronze	Rod	60.	39.25	0.75	75 000	54 000	60 000	40 000	25.0	50.0	100	89
Tobin Bronze	Sheet	60.	39.25	0.75	100 000	54 000	......	40 000	4.0	40.0	165	90
Signal Bronze	Wire	98.25	....	1.25	100 000	50 000	......	......	3.0[a]	33.0[a]	...	..

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[a] Elongation in 10 in. for diameter over 0.206 in. and in 50 in. for diameter less than 0.204 in.

FROM BELL TELEPHONE LABORATORIES, INC.

	Approximate Composition, per cent				Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent
	Cu	Zn	Pb	Fe			
Sheet							
A, spring temper	64.5 to 67.5	Bal.	0.3[a]	0.05[a]	90 500	31 300	2.0
B, spring temper	61 to 64	Bal.	1.25 to 2.0	0.06[a]	90 000	......	4.0
C, hard temper	83 to 85	Bal.	0.15[a]	0.05[a]	48 000	......	...
D,	73 to 76	Bal.	0.25[a]	0.05[a]	......	......	...
E, hard temper	64 to 67	Bal.	0.8 to 1.1	0.08[a]	52 000	......	...
G, spring temper	70.5 to 73.5	Bal.	0.1[a]	0.05[a]	93 000	......	...
Hardware Bronze	89.0	9.0	2.0	....	33 000 to 60 000	25 000	4.0

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[a] Maximum.

FROM OTHER SOURCES

Brass. Spring Wire.

Cu, 70–74; Tens. Str., 100,000 lb. per sq. in., minimum.

Cu, 64–68; Tens. Str., 100,000 lb. per sq. in., minimum.

		Tensile Strength, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness Number
Cu, 90; Zn, 10	Rolled, Hard	55 000	5	....	60
	Rolled, Soft	37 000	40	70	47
	Sand Cast	29 000	22	....	....
Cu, 80; Zn, 20	Rolled, Hard	75 000	5	....	75
	Rolled, Soft	42 000	50	85	46
	Sand Cast	35 000	31	32	....
Cu, 70; Zn, 30	Sand Cast	40 000	35	....	37
Cu, 66; Zn, 34	Rolled, Hard	60 000	5	....	75
	Rolled, Soft	48 000	50	85	45
Cu, 60; Zn, 40	Rolled, Hard	70 000	30	50	....
	Sand Cast	45 800	15	22	....
Cu, 51.2; Zn, 48.8	Cast	60 200	19	21.5	108
	Forged	74 800	37	33.5	114
	Forged, anneal 650° C.	64 900	25	27	108
Cu, 50; Zn, 50	Cast	20 000	1	1.5	108
	Forged	35 400	5	5.5	117
Manganese Bronze	Sand Cast	70 000 75 000	30 to 22	32 to 25	110 to 120
	Chill Cast	75 000 80 000	32 to 25	34 to 28	120 to 130
	Rolled	100 000	12 to 15	....	....

High Tensile:

Cu, 68.5; Al, 6.5; Mn, 2.2; Fe, 2.5.

Forged; Tens. Str., 101,000 to 110,000 lb. per sq. in.; Yield Point, 50,000 to 57,000 lb. per sq. in.; Elongation in 2 in., 5 to 10 per cent; Brinell Hardness Number, 200 to 220.

Scovill Hardware Bronze:

Cu, 89; Ni, 1; Pb, 2; Zn, Bal.

Soft; Tens. Str., 40,000 lb. per sq. in.; Yield Point, 17,000 lb. per sq. in.; Elongation in 2 in., 45 per cent; Reduction of Area, 70 per cent.

4 Hard; Tens. Str., 69,000 lb. per sq. in.; Yield Point, 65,000 lb. per sq. in.; Elongation in 2 in 5 per cent; Reduction of Area, 60 per cent.

BRONZES

	CU	SN	ZN	PB	P	OTHER ELEMENTS AND COMMENTS
Acid Bronze	88.00	10.00	....	2.00	....	
Acid Bronze	82.00	8.00	2.00	8.00	....	
Acid Bronze	84.00	9.50	....	6.30	0.20	
Agrilite, No. 5	70.5	5.4	....	24.	Trace	Ni, 0.1; Brinell Hardness 40.3
Ajax Phosphor	79.30	10.00	....	10.00	0.7	
Ajax Plastic	64.00	5.00	....	30.00	....	Ni, 1
Allan No. 2 Bronze	66.	9.	....	25.	....	
Allan Red Metal	50.00	....	....	50.00	....	S, 0.25
Allan Red Bronze	62.50	7.50	....	30.00	....	
Amax Metal	81.30	11.00	....	7.40	0.3	
Argental	85.00	10.00	....	....	....	Co, 5.0
Arsenic	79.7	10.00	....	9.50	....	As, 0.8
Baily's Metal	82.1	12.8	5.1	....	....	
Bearing Bronze (Kaiser):						
Locomotive	74.	10.	9.	7.	....	
Prussian	84.	15.	1.	....	....	
Belgian	80.	16.	....	2.0	....	Sb, 2.
French (Northern)	82.	10.	8.	....	....	
Russian	77.	10.2	5.1	7.7	....	
Railroad Cars	82.	18.	....	....	....	
Railroad Cars	84.	16.	....	....	....	
Railroad Cars	75.	20.	5.	....	....	
Rheinland	86.	12.	2.	....	....	
E.B.D., Breslau	88.	10.	2.	....	....	5 per cent of Phos. Tin
E.B.D., Berlin	90.	10.	....	....	..	
Automobile	88.	8.	....	3.	....	1 per cent of Phos. Tin
Automobile	78.	8.	1.	12.	....	1 per cent of Phos. Tin
Automobile	80.	10.	....	8.	....	2 per cent of Phos. Tin
Various	83.	14.	2.	1.	....	
	83.7	14.2	2.1	....	....	
	85.5	12.8	1.7	....	....	
	83.	12.	5.	....	....	
	85.	11.	4.	....	....	
	74.5	9.5	8.9	7.1	....	
	77.	9.	14.	....	....	
	83.7	8.8	7.5	....	....	
	84.	8.	....	8.	....	
	81.	7.	3.	9.	....	
	78.	7.	....	15.	....	
	70.	6.5	2.	1.5	....	
	86.	6.	5.	....	....	Mn, 2.7
	72.4	4.7	29.9	1.5	....	
	75.	4.	21.	....	....	
Bearings of Engines	79.	8.	5.0	8.0	....	
Bearings and Valves	80.	16.	....	2.	....	Sb, 2
Bell Metal	75–80	25–20	....	....	....	
"Best"	78.	22.	....	....	....	

BRONZES (*Continued*)

	Cu	Sn	Zn	Pb	P	Other Elements and Comments
Reichenhall, 600 years	76.2	23.8	....	....	....	
Reichenhall, 300 years	80.	20.	....	....	....	
Old Bell at Rouen	71.	26.	1.8	1.2	....	
Damstadt	73.94	21.67	....	2.11	....	Fe, 0.19; Ni, 2.
Damstadt	72.52	21.06	....	2.14	....	Fe., 0.05; Ni, 2.66
Musical	84.	16.	....	....	....	
House	80.	20.	....	....	....	
Clock	75.	25.	....	....	....	
Herbohn	60.	35.	5.0	....	....	
Herbohn	71.43	26.4	2.7	....	....	
Karakane	71.42	14.2	....	14.3	....	
Karakane	70.	19.	3.	8.	....	
Karakane	65.95	17.25	3.45	10.35	....	
Karakane	64.	24.	9.	....	....	Fe, 3.0
Karakane	62.5	25.	9.4	....	....	Fe, 3.1
Karakane	61.	18.	6.	12.	....	Fe, 3.0
Bilgen-Bronze	97.32	1.89	....	0.24	....	Fe, 0.52
Bow Wire	93.	5.	2.	....	....	
Bridge Bronze A	80.	20.	....	....	0.1	
Bridge Bronze B	85.	15.	....	....	0–1	
Bridge Bronze C	80.	10.	....	10.	0.7–1	
Bridge Bronze D	88.	10.	2.	....	0.25	
Bismuth Bronze	53.	15.	20.	....	....	Ni, 10.; Al, 1.; Bi, 1.
Brasses	74.4	9.5	8.9	7.1	....	
Brasses	70.	10.	10.	10.	....	
Brasses	74.	1.0	10.	15.	....	
Bushings	86.2	10.2	3.6	....	....	
Bushings	85.	11.	4.	....	....	
Camelia	70.4	4.2	10.2	14.7	....	Fe, 0.5
Carbon	75.47	9.72	....	14.57	....	C, 0.24
Carriage Wheel Bearing	84.	16.	....	....	....	
Ceco Bearing	62.5	4.6	....	31.9	....	Ni, 0.9
Chinese	72.5	4.7	14.3	18.5	....	
Chinese	74.	1.0	10.	15.	....	
Cocks	88.	10–8	2–6	....	....	
Cogs and Worms	85.	11.	4.	....	....	
Coinage	95.	4.	1.	....	....	
Coinage	95.	3.	2.	....	....	
Cooper's Speculum	57.8	27.3	3.6	....	....	As, 1.2; Pt, 10.
Cornish	77.8	9.6	....	12.6	0.8	
Damascus	77.	10.5	....	12.5	....	
Damar	76.4	10.6	....	12.5	....	
Daimler Bearing	76.	3.	20.	1.	....	
Dawson	83.9	15.9	....	0.1	Trace	
Delta No. 5	81.1	10.5	0.1	7.4	....	Sb, 0.76
Demo Bronze	61.	4–6	....	33.	....	Ni, 1–2
Dick's Bearing	80.	10.	....	10.	....	
Dudley's B	77.	8.	....	15.	....	
Dudley's K	77.	10.5	....	12.5	....	
Dudley's Phosphor	79.7	10.	....	9.6	0.8	
Durex	83.2	10.	....	....	....	C, 4.7–4.4; Brinell Hardness, 40–30
Dysoid	62.	10.	10.	18.	....	
Edward's Speculum	63.3	32.2	....	....	....	As, 1.6
Edward's Speculum	69.8	25.1	2.6	....	....	As, 2.4
Einheits Red Brass	85.	9.	6.	....	....	
Eisen-Bronze	82.5	8.55	4.45	....	....	Fe, 3.95
Eislers	94.1	5.9	....	....	....	
Eccentric Ring	84.	14.	2.	....	....	
English Penny Bronze	95.5	3.	1.5	....	....	

BRONZES (*Continued*)

	Cu	Sn	Zn	Pb	P	Other Elements and Comments
Ferro Bronze	90.7	....	....	....	....	Fe, 8; Cr, 0.72
File Metal (Genfer)	64.4	18.	10.	7.6	....	
File Metal (Genfer)	62.	20.	10.	8.	....	
File Metal (Vogel)	73.	19.	8.	8.	....	
File Metal	61.5	31.	....	8.5	....	
File Metal	51.	28.5	7.	7.	....	
Flange Metal (German)	92.4	2.5	5.05	....	....	
Flange Metal (French)	94.35	5.6	...	0.05	...	
Gearing	91.3	8.7	...	...	...	
Gear Bronze	88.	10.	....	....	2.	
Gear Bronze	85.	13.	2.	....	....	
Gears	85.	10.	3.	2.	....	
Genelite	70.2	13.7	1.5	9.	0.05	Fe, 0.22; Gr, 5.35; Brinell Hardness, 21.6
Gold Bronze	90.5	6.5	3.	....	....	
Gun Metal, Sheet	90.	10.	....	....	....	
Gun Metal, Cast	88.	8.	4.	....	....	
French, Modern	90.1	9.9	....	....	....	
French, Old	89.44	8.91	1.39	0.16	....	
Prussian, Modern	90.9	9.1	....	....	....	
English, Modern	89.3	10.7	....	....	....	
English, Modern	91.74	8.26	....	....	....	
Russian, Modern	90.8	9.2	....	....	....	
Russian, 1813	88.61	10.7	....	....	....	Fe, 0.69
Swiss (Lucern)	88.93	10.37	0.42	....	....	
Cochin China	77.18	3.42	5.02	13.22	....	Fe, 1.16
Cochin China	93.19	5.43	....	....	....	Fe, 1.38
Chinese, Old	71.16	....	27.36	....	....	Fe, 1.40
Chinese, 1901	93.2	5.05	....	....	....	Fe, 1.72
Turkish, 1464	95.2	4.71	....	....	....	
Turkish, 1907	90.9	8.8	....	....	....	Fe, 0.2
Gun Mount	80.	3.	17.	....	....	
Graney Bronze (Law)	75.8	9.2	15.	....	....	
Gurney's	75.8	9.2	15.	....	....	
Hairsprings	Bal.	4.5–6.5	....	....	0.2	Annealed at 200° C.
Hercules	85.5	10.	2.	....	....	Al, 2.5
High Temperature	90.7	2.7	6.3	1.3	....	
Holfos Bronze	87.4	12.	....	0.2	0.4	
Hydraulic	83.0	10.8	6.0	0.1	....	
Instrument	82.	13.	5.	....	....	
Instrument	82.1	12.8	5.1	....	....	
Johnson Locomotive Bearing	87.5	7.85	5.07	....	....	
Kelmet	67.8–70.4	6.4–6.6	Trace	22.7–25.5	....	Brinell Hardness, 50
Kern's Hydraulic	78.	12.	10.	....	....	
Kochlin's Bearing	90.	10.	....	....	....	
Kuhne Phosphor Bronze	78.	10.6	....	10.45	0.57	Ni, 0.26
Lafond's Axle Bearing	80.	18.	2.	....	....	
Lafond's Bronze	83.	15.	1.5	0.5	....	
Lafond's Straps	84.	14.	2.	....	....	
Lafond's Pumps	88.	10.	2.	....	....	
Lafond's Heavy Bearing	83.	15.	1.5	0.5	....	
Lafond's Malleable	98.04	1.96	....	....	....	
Litinum Bronze	90.	4.7	3.86	1.6	....	
Lowroff Phosphor Bronze	70.	13.	....	16.	1.	
Lowroff Phosphor Bronze	90.	4.	....	5.5	0.5	
Laderig's Speculum	69.	28.7	....	....	....	
Lumen Alloy 48	84.	10.	....	2.5	....	Ni, 3.5; Deoxidized with P
Lumen Alloy 54	85.	10.	....	5.	....	Deoxidized with P
Medal	92.	8.	....	....	....	
Medal	85.	4.	1.	....	....	

BRONZES (*Continued*)

	Cu	Sn	Zn	Pb	P	Other Elements and Comments
Medal	97.	1.	2.	....	....	
McKechnie's	57.	41.	1.	0.5	....	Fe, 1
Manheim Gold	83.7	7.	9.3	....	....	5 per cent of Phos. Tin
Manganese Bronze	82.	8.	5.	3.	....	Mn, 2.0
Manganese Bronze	83.5	8.	5.	3.	....	Mn, 0.5
Mira Metal	75.	8.	....	16.	....	Ni, 1
Moore-Jones Bearing	81.6	5.2	4.8	8.5	....	Ni, 0.3
Mudge's Speculum	68.82	31.18	....	....	....	
Naval Gun Metal, G	88.	10.	2.	....	....	
Naval Journal, H	83.	13.5	3.5	....	....	
Naval Journal, HX	83.	13.5	....	3.5	....	
Naval Valve, M	87.	7.	6.	....	....	
Naval Phosphor, Cast, P-c	88.	8.	2.5	....	0.5	
Naval Phosphor, Rolled, P-r	95.	4.5	....	....	0.5	
Needle	84.5	8.	5.5	2.	....	
Neogen	58.	2.	27.	....	....	Ni, 12.; Al, 0.5; Bi, 0.5
Nickel Bronze	83.5	10.	....	3.	....	Ni, 3.5; Tens. Str., 38,000 to 47,000 lb. per sq. in.; Elongation, 12 to 7 per cent.
Noil, piston rings	80.	20.	....	....	....	
Nongran	87.	11.	2.	....	....	
Oil Cups	88.	5.	7.	....	....	
Oil Pump	83.	3.	9.	....	3.	
Ounce Metal	85.	5.	5.	5.	....	
Ormulu	58.	16.7	25.3	....	....	
Ormulu, small	94.12	5.88	....	....	....	
Ormulu, large	90.5	65.	3.0	....	....	
Perking Brass	76.2	23.8	....	....	....	
Perking Brass	80.	19.82	0.14	....	....	
Phono Electric	98.75	1.25	....	....	....	
Phono Hi-Strength	97.	2.	....	....	....	Si, 1
Phosphor Bronze:						
Charpy	85.7	12.2	....	....	0.4	
Charpy	84.8	13.4	....	....	0.46	
Law	87.6	10.8	....	....	1.0	
Law	88.7	9.5	....	....	0.7	
Bridge	80.	20.	....	....	1–0.2	
Bridge	85.	15.	....	....	1.	
Bearings	83.	14.	2.	1.	1.	
Bearings	88.1	8.	....	10.	0.15	
Bushings	79.	10.	....	10.	0.7	
Gears	88.	10.	....	2.	0.1	
Gears	85.	13.	2.	....	0.1	
Gears	79.	12.	....	7.5	0.1	
English	79.2	10.2	....	9.6	0.97	
Pennsylvania Railroad	79.7	10.	....	9.5	0.8	
Pennsylvania Railroad "B"	76.8	8.	....	15.	0.2	
Pennsylvania Railroad "B"	85.55	9.85	3.77	0.62	0.05	
Pennsylvania Railroad "B"	80.	8.	....	10.	....	2 per cent of Phos. Tin
Rolling	95.6	4.5	....	....	0.1	
Russian	93.7	5.8	0.34	....	0.17	
Hairsprings	93.	6.6	....	....	0.12–0.2	
Wire	98.75	1.2	....	....	0.05	
Hard	92.8	7.	....	....	0.2	
Very Hard	80.	9.	....	....	1.0	
Pinkus Bronze	72.4	14.7	1.5	8.8	....	Sb, 2.5
Piston Rings	84.	2.9	8.3	4.3	....	
Railroad (Hughes):						
Slide Valves	84.5	10.	....	5.	0 5	

BRONZES (*Continued*)

	Cu	Sn	Zn	Pb	P	Other Elements and Comments
Injector	84.	8.5	5.	2.5	....	
Phosphor Bronze	88.5	10.	....	....	0.5	
Axle Box Bearing	80.	5.	....	15.	....	
20-Ton Wagon	75.	5.	....	20.	....	
Railroad (Thurston):						
Axle Bearings, French	82.	10.	8.	....	....	
Axle Bearings, Common French	78.	20.	2.	....	....	
Axle Bearings, Lafond	80.	18.	2.	....	....	
Axle Bearings, Hard	87.05	7.88	5.07	....	....	
Eccentric Strap, Dutch	85.25	12.75	2.0	....	....	
Eccentric Strap, Lafond	84.	14.	2.0	....	....	
Gearing	88.8	8.5	2.7	....	....	
Locomotive Bearings	89.	2.4	7.8	....	....	Fe, 0.8
Locomotive, German	81.17	....	15.2	14.6	....	Fe, 0.9
Locomotive, Durable	73.5	9.5	9.5	7.5	....	Fe, 0.5
Pistons and Rods	74.1	3.7	22.2	....	....	
Reichsbahn Alloys:						
Einheits Red Brass	85.	9.	6.	....	....	
Bearings	85.	11.	4.	....	....	
Valves, Slides	85.	9.	6.	....	....	
Pipe Flanges	91.	5.	4.	....	....	
Machinery Castings	82.	10.	7.	1.	....	
Machinery Castings	85.	5.	8.	2.	....	
Dynamo & C. R. Bearings	86.	10.	....	4.	....	
Heavy Duty Bearings	77.	8.	....	15.	....	
Car Journal Bearings	79.	20.	....	....	....	
Heavy Duty Bearings	85.	14.	....	....	....	
Worm Wheels	89.	10.	....	....	....	
Reith's Alloy	74.5	11.6	....	9.	....	Sb, 4.9
Richardson's Speculum	65.3	30.	0.7	....	....	As, 2.0; Si, 2.
Roman Bronze	90.	9.	....	....	....	
Ross' Alloy	68.2	31.8	....	....	....	
Sabeco Bearing	70.5	9.2	....	21.0	....	
Sallit's Speculum	64.6	31.3	....	....	....	Ni, 4.1
Sheet Bronze	90.	10.	....	....	....	
Sheet Phosphor	94.5	5.0	....	....	....	0.5 per cent of Phos. Tin
Sheet Phosphor	95.	4.	....	....	....	1.0 per cent of Phos. Tin
Sashchain	92.	8.	....	....	....	
Sashchain	95.	5.	....	....	....	
Screw-Nut	86.	11.4	2.3	....	....	
Slide Valve	88.5	2.5	9.	....	....	
Steam Fittings	88.	8.	2.	2.	....	
Silicon Bronze	98.55	1.45	....	....	....	Si, 0.05
Silicon Bronze	91.	9.	....	....	....	Si, 0.05
Similor	83.7	7.	9.3	....	....	
Statuary Bronze:						
Augsburg	89.43	8.17	....	1.05	0.34	Ni, 0.19
Augsburg	94.74	1.64	0.54	6.24	....	Ni, 0.71
Bacchus, Potsdam	89.34	7.5	1.63	1.21	0.18	
Bavaria, Munich	91.55	1.77	5.5	1.3	....	
Column Vendome	89.2	10.2	0.5	0.1	....	
Column of July, Paris	91.4	1.6	5.6	1.4	....	
Frederick the Great, Berlin	88.3	1.4	9.5	0.7	....	
Germanicus, Potsdam (1820)	89.78	6.16	2.35	1.33	....	Ni, 0.27
Grosser Kurfürst, Berlin	89.09	5.82	1.64	2.62	0.13	
Henry IV, Paris	89.62	5.7	4.2	0.48	....	
Louis XIV, Paris (1699)	91.4	1.7	5.53	1.37	....	
Mars and Venus, Munich	94.12	4.77	0.3	0.67	....	Ni, 0.48
Melanchton, Wittenberg	89.55	2.99	7.45	....	....	
Munich	92.88	4.18	0.44	2.31	0.15	

BRONZES (*Continued*)

Statuary Bronze (*Continued*);	CU	SN	ZN	PB	P	OTHER ELEMENTS AND COMMENTS
Munich	77.03	0.91	19.12	2.29	0.12	Ni, 0.43
Napoleon I, Paris	75.0	3.0	20.	2.0	....	
The Shepherd, Potsdam	88.68	9.2	1.28	0.77	....	
Speculum, Cu_4Sn	68.25	31.75	....	....	....	
Speculum, English	66.6	33.4	....	....	....	
Speculum, Chinese	80.8	10.7	....	....	....	Sb, 8.5
Speculum, Chinese (Elsner)	80.8	....	....	....	....	Pb, 9.1; Sb, 8
Schmidt Locomotive Bearing	86.	14.	....	....	....	
Seraing Bearing	86.	14.	....	....	....	
Seraing Piston Rings	89.	2.	9.	....	....	
Stephenson, Locomotive Bearing	79.5	7.5	5.0	8.0	....	
Stephenson, Piston Rings	84.	2.9	8.3	4.3	....	Fe, 0.4
Stone's English Gear	89.	11.	....	....	0.3	
Telegraph Bronze	80.	5.	7.5	7.5	....	
Tin Bronze	89.	11.	....	....	....	
Tungsten Bronze	90.	....	....	....	....	W, 10.
Uchatius Bronze	92.	8.	....	....	....	
Ulcony	65.	....	....	35.	....	
Valves	85.	9.	6.	....	....	
Valve Bronze	89.	5.	3.	3.	....	
Valve Bronze	83.	4.	7.	6.	....	
Valve, Steam	88.	10.	2.	....	....	
Weights	90.	8.	2.	....	....	
Whistles	80.	18.	2.	....	....	
Whistles, Lafond	81.	17.	2.	....	....	
Whistles, Lafond	80.	18.	....	....	....	Sb, 2.0
Wire	98.75	1.2	....	....	0.05	

PHYSICAL PROPERTIES OF ALLOYS FROM A.S.T.M. SPECIFICATIONS FOR BRONZE

B 10 - 18. The Alloy 88-10-2. (S.A.E. 62.)
Cu, 86-89; Sn, 8-11; Zn, 1-3; Tens. Str., 30,000 lb. per sq. in.; Elongation in 2 in., 14 per cent.

B 60 - 28. Sand Cast.
Cu, 88; Sn, 8; Zn, 4; Cu, 86-89; Sn, 7.5-11; Zn, 1.5-4.5; Pb, 0.3, max.; Ni, 0.5; Sb, 0.25; Fe, 0.1.
Tens. Str., 40,000 lb. per sq. in.; Yield Point, 15,000 lb. per sq. in; Elongation in 2 in., 20 per cent.

B 61 - 28. Steam or Valve Bronze Sand Castings.
Cu, 86-91; Sn, 6-7; Pb, 1-2; Ni, 0.5, maximum; Sb, 0.25.
Tens. Str., 32,000 lb. per sq. in.; Yield Point, 16,000 lb. per sq. in.; Elongation in 2 in., 17 per cent.

B 62 - 28. Ounce Metal. (S.A.E. 40.)
Cu, 84-86; Sn, 4-6; Zn, 4-6; Pb, 4-6; Ni, 0.75, maximum; Fe, 0.25; Sb, 0.25.
Tens. Str., 26,000 lb. per sq. in.; Yield Point, 12,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

B 31 - 21. Bronze Bearing Metal Ingot.

	COPPER, PER CENT	TIN, PER CENT	LEAD, PER CENT	PHOSPHORUS, PER CENT	ZINC, PER CENT MAX.	ANTIMONY, PER CENT	IRON, PER CENT	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT
Grade No. 1	85.	10.	5.	0.7[a]	0.25	0.75	0.25	28 000	12.5
Grade No. 2	80.	10.	10.	0.7	0.5	0.75	0.25	25 000	8
Grade No. 3	80.	10.	10.	0.05[b]	2.0	0.75	0.25	22 000	8
Grade No. 4	77.	8.	15.	0.25[b]	0.5	0.75	0.25	20 000	10
Grade No. 5	73.	7.	20.	0.05[b]	0.5	0.75	0.25	18 000	7
Grade No. 6	70.	5.	25.	0.0	0.5	0.75	0.25	15 000	5

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[a] Minimum.
[b] Maximum.

B 22 – 21. Bronze Bearing Metal for Turntables.
Class A. Cu, Bal.; Sn, 20, maximum; P, 1.0, maximum. Compression, 24,000 lb. per sq. in.
Class B. Cu, Bal.; Sn, 17, maximum; P, 1.0, maximum. Compression 18,000 lb. per sq. in.
Class C. Cu, 82, maximum; Sn, 11; Pb, 11; P, 0.7–1.0.
Class D. Cu, 89, max.; Sn, 11, max., Zn, 2.25, max.; P, 0.25, max.; Fe, 0.2, maximum.
Tens. Str., 33,000 lb. per sq. in.; Elongation in 2 in., 14 per cent.

B 66 – 28. Bronze Castings for Locomotive Wearing Parts.
Phosphor Bronze. Pb, 8–11; Sn, 9–11; Zn, 0.5, max.; P, 0.4–0.8 (Sn + Pb + P + Cu, 99, min.).
Hard Bronze. Pb, 10–15; Sn, 7–10; Zn, 1.25, max.; (Pb + Sn, 22, max.; Sn + Pb + Cu + Zn, 99.25, min.).
Medium Bronze. Pb, 14–22; Sn, 6–8; Zn, 1.25, max.; (Pb + Sn, 28, maximum; Sn + Pb + Cu + Zn, 99.25, min.).
Soft Bronze. Pb, 23–27; Sn, 4–6; Zn, 0.75, max. (Pb + Sn, 31, maximum; Sn + Pb + Cu + Zn, 99.25, min.).

B 67 – 28. Car and Tender Journal Bearings. Lined.
Pb, 15–22; Sn, 5–7 (Sn + Pb + Cu, 97, min.; Bal. 3, excluding Zn, 1).
Sn, as specified; Sb, 8, min.; Sn + Sb, 10–14; As, 0.2, max.; Cu, 0.5 (Sn + Sb + Pb + As, 99.25).

PHYSICAL PROPERTIES OF ALLOYS FROM U. S. NAVY SPECIFICATIONS FOR BRONZE

Composition G. Gun Metal (46 M 6 e). Steam Valves, etc.
Cu, 86–89; Sn, 7.5–11; Zn, 1.5–4.5, max.; Ni, 0.75; Pb, 0.3; Fe, 0.1; Sb, 0.25; P, 0.05.
Tens. Str., 40,000 lb. per sq. in.; Elongation in 2 in., 20 per cent.

Composition H. Journal Bronze. (46 B 9 c)
Cu, 82–84; Sn, 12.5–14.5; Zn, 2.5–4.5; Pb, 1, maximum; Fe, 0.1.

Composition M. Valve Castings. (46 B 8 d)
Cu, 86–91; Sn, 6–7; Zn, 1.5–5; Pb, 1–2 Ni, 0.75, maximum; Fe, 0.15; Sb, 0.25; P, 0.05;
Tens. Str., 32,000 lb. per sq. in.; Elongation in 2 in., 17 per cent.

Composition P-c. Phosphor Bronze Castings. (46 B 5 f)
Cu, 85–89; Sn, 7.5–11; Zn, 1.5–4.5; Ni, 0.75, maximum; P, 0.5; Sb, 0.25; Fe, 0.25; Pb, 1;
Tens. Str., 35,000 lb. per sq. in.; Elongation in 2 in., 18 per cent.

Composition P-r. Phosphor Bronze Rolled or Drawn. (46 B 14 d)
Cu, 94, min.; Sn, 3.5, min.; P, 0.05–0.5; Pb, 0.2, max.; Fe, 0.1. (Cu + Sn + P over 99.)

DIAMETER OF RODS, IN.	TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	BEND, DEG.
Up to $\frac{1}{2}$	80 000	60 000	12	120
$\frac{1}{2}$ to 1	60 000	40 000	20	120
1 to 3	55 000	30 000	25	120
Over 3	50 000	25 000	25	120
Sheets, etc., spring temper	90 000	......	..	...
Sheets, etc., medium temper	50 000	25 000	25	...

Phosphor Bronze Spring Wire. (22 W 5 c)
Cu, 94, minimum; Sn, 3.5, minimum; P, 0.05–0.5, etc.
Diameter, 0.025 in.; Tens. Str., 150,000 lb. per sq. in.; Elongation in 2 in., 1 per cent.
Cu, 94, minimum; Sn, 3.5, minimum; P, 0.05–0.5, etc.
Diameter, 0.375 in.; Tens. Str., 105,000 lb. per sq. in.; Elongation in 2 in., 9 per cent.

Bronze Bearing Castings. (46 B 22 a)
1. Cu, 73–80; Sn, 5–7; Zn, 0–0.5; Pb, 15–20; Ni, 1, maximum; P, 0.05; Fe, 0.25; Sb, 0.25.
2. Cu, 82–85; Sn, 7–9; Zn, 0–0.25; Pb, 7–9; Ni, 1, maximum; P, 0.3–0.6; Fe, 0.15; Sb, 0.15;
Tens. Str., 25,000 lb. per sq. in.; Elongation in 2 in., 8 per cent.
3. Cu, 84–86; Sn, 13–15; Zn, 0–0.15; Pb, 0.2, maximum; Ni, 0.75; P, 0.05; Fe, 0.1; Sb, 0.15;
Tens. Str., 30,000 lb. per sq. in.; Elongation in 2 in, 1–8 per cent.
4. Cu, 80–82; Sn, 18–20; Zn, 0.25, maximum; Pb, 0.5; Ni, 0.75; P, 0.4–0.6; Fe, 0.1; Sb, 0.15;
Tens. Str., 45,000 lb. per sq. in.; Brinell Hardness, 160

PHYSICAL PROPERTIES OF ALLOYS FROM AMERICAN BRASS CO. FOR BRONZE

Material	Form	Approximate Composition, per cent			Tensile Strength, lb. per sq. in.		Yield Point, lb. per sq. in.		Elongation in 2 in., per cent		Brinell Hardness Number	
		Cu	Sn	P	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Phosphor Bronze.	Sheet	96.0	3.75	0.25	90 000	45.0	81.5	18.3	4.0	50.0	180	60
Chain Bronze....	Sheet	95.0	5.0	....	110 000	50.0	97.0	47.0	5.0	55.0	140	60
Phosphor Bronze.	Wire	93.75	6.0	0.25	150 000	60.0	....	....	1.0[a]	48.0[a]	...	..
Gun Metal.......	Sheet	92.0	8.0	....	110 000	55.0	85.0	25.0	3.0	70.0	180	70
Coe Bronze......	Sheet	89.5	10.5	....	115 000	60.0	95.0	40.0	5.0	65.0	190	74

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[a] Elongation in 10 in. for diameter over 0.206 in.

PHYSICAL PROPERTIES OF BRONZE FROM BELL TELEPHONE LABORATORIES, INC.

	Composition, per cent						Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent
	Cu	Sn	Pb	P	Ni	Si			
Barberite, cast....	88.5	5.0	......	....	5.0	1.5	60 000	48 000	6.8
Phosphor-Bronze:									
A sheet, spring..	94.4[a]	3.8 to 4.8	......	0.05 to 0.35	...	...	98 000	......	...
C sheet, spring..	91.0[a]	7.5 to 8.5	......	0.05 to 0.25	...	...	110 700	......	3.0
D sheet, spring.	90.0[a]	4.0 to 5.5	2.5 to 4.0	0.05 to 0.25	...	...	100 000	......	3.5

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[a] Minimum.

PHYSICAL PROPERTIES OF ALLOYS FROM S.A.E. SPECIFICATIONS FOR BRASS AND BRONZE

S.A.E. 41. Yellow Brass.
Cu, 62–65; Pb, 2–4; Zn, 31–36;, Sn 1, maximum; Fe, 0.5.
Tens. Str. 25,000 lb. pei sq. in.; Yield Point, 12,000 lb. per sq.in.; Elongation in 2 in., 20 per cent.

S.A.E. 42. White Nickel Brass.
Cu, 55–64; Ni, 18, minimum; Fe, 0.35, maximum; Zn, Bal.
Tens. Str., 30,000 lb. per sq. in.; Elongation in 2 in., 20 per cent.

S.A.E. 43. Mn Bronze Castings.
Cu, 53–62; Zn, 38–47; Pb, 0.15, maximum (Sn., Fe., Mn., Al.).
Tens. Str., 60,000 lb. per sq. in.; Yield Point, 30,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

S.A.E. 44. Cast Brass (Brazed).
Cu, 83–86; Zn, 14–17; Pb, 0.5, maximum; Fe, 0.15.

S.A.E. 63. Leaded Gun Metal.
Cu, 86–89; Sn, 9–11; Pb, 1–1.25; P, 0.25, maximum; Zn, 0.5.
Tens. Str., 30,000 lb. per sq. in.; Yield Point, 12,000 lb. per sq. in.; Elongation in 2 in., 10 per cent.

S.A.E. 65. Phosphor Gear Bronze.
Cu, 88–90; Sn, 10–12; P, 0.1–0.3; Pb, Zn, 0.5, maximum.
Tens. Str., 35,000 lb. per sq. in.; Yield Point, 20,000 lb. per sq. in.; Elongation in 2 in., 10 per cent.

S.A.E. 66. Bronze for Lined Bearings.
Cu, 83–86; Sn, 4.5–6; Pb, 8–10; Zn, 2.0, maximum.
Tens. Str., 25,000 lb. per sq. in.; Yield Point, 12,000 lb. per sq. in.; Elongation in 2 in., 8 per cent.

S.A.E. 69. Wrought Al-Bronze.

S.A.E. 74. Seamless Brass Tubing, Annealed.
Cu, 60, minimum; Pb, 1, maximum; Fe, 0.1, maximum; Zn, Bal.
Tens. Str., 40,000 lb. per sq. in.; Elongation in 2 in., 25 per cent.

S.A.E. 76. Naval Brass (Tobin Bronze) Tubing.

Cu, 59–62; Sn, 0.5–1.5; Pb, 0.3, maximum; Fe, 0.1; Zn, Bal.

Wall Thickness, in.	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent
Up to $\frac{1}{8}$............	60 000	24 000	28
$\frac{1}{8}$ to $\frac{1}{4}$.............	55 000	22 000	32
Over $\frac{1}{4}$.............	50 000	20 000	35

S.A.E. 77. Phosphor Bronze Strip.

A. Cu, Bal.; Sn, 4–6; P, 0.03–0.4; Zn, 0.2, maximum: Pb, 0.1; Fe, 0.1.
B. Cu, Bal.; Sn, 7–9; P, 0.03–0.2; Zn, 0.2, maximum; Pb, 0.1; Fe, 0.1.

	Tensile Strength of A, lb. per sq. in.	Elongation of A, per cent	Tensile Strength of B, lb. per sq. in.	Elongation of B, per cent
Half Hard.......	55 000	15	65 000	20
Hard...........	75 000	5	85 000	7.5
Extra Hard......	85 000	2	100 000	1.0
Spring..........	90 000	1	......	...

S.A.E. 80. Brass Wire for Springs.

A. Cu, 70–74; Pb, 0.1; Fe, 0.06; Zn, Bal.
Tens. Str., 100,000 lb. per sq. in.: Bend, 180 deg. over 1 diameter.
B. Cu, 64–68; Pb, 0.1; Fe, 0.07; Zn, Bal.
Tens. Str., 100,000 lb. per sq. in; Bend, 180 deg. over 1 diameter.

S.A.E. 81. Phosphor Bronze Wire.

Cu, Bal.; Sn, 4–6; P, 0.03–0.4, maximum; Zn, 0.2; Pb, 0.1; Fe, 0.1.
Up to 0.0625 in., Tens. Str., 130,000 lb. per sq. in.
0.0625 to 0.125 in., Tens. Str., 120,000 lb. per sq. in.
0.125 to 0.25 in., Tens. Str., 110,000 lb. per sq. in.
0.25 to 0.375 in., Tens. Str., 100,000 lb. per sq. in.

S.A.E. 82. Brass Wire for Brazing.

Cu, 59–62; Pb, 0.3, maximum; Fe, 0.06; Al, 0; Zn, Bal.

COPPER ALLOYS—TENSILE STRENGTH AND CONDUCTIVITY (BASSETT)

	Tensile Strength, lb. per sq. in.	Elongation in 10 in., per cent	Conductivity, per cent
Copper, No. 9 Hard..............................	60 000	1.6	97.5
Cd, 1.18 per cent; No. 9 Hard.....................	81 200	1.4	85.7
Cd, 1.2 per cent; No. 6 Hard......................	71 000	2.0	77.8
Cd, 0.5 per cent; Sn, 0.42 per cent; No. 9 Hard......	81 180	1.8	65.4
Be, 0.20 per cent; No. 6 Hard.....................	77 000	1.3	60.5
Cd, 0.90; Sn, 0.9; No. 9 Hard.....................	95 500	2.2	51.0
Be, 0.4 per cent; No. 6 Hard......................	86 800	1.5	46.8
Sn, 1.75 per cent; No. 9 Hard.....................	96 500	2.1	37.9
Si, 1.0 per cent; No. 9 Hard......................	80 500	2.2	16.5
Sn, 2 per cent; Si, 0.5 per cent; No. 9 Hard.........	117 000	2.1	15.5
Be, 1.25 per cent; No. 6 Hard.....................	144 100	0.92	22.9
Be, 1.62 per cent; No. 6 Hard.....................	145 400	1.07	19.9

COPPER-NICKEL ALLOYS

	Cu	Ni	Other Elements and Comments
Adnic...	70.	29.	Sn, 1
Adnic...	68.4	29.3	Sn, 0.96; Mn, 1.1; Fe, 0.2
Alpro..	50.	50.	
Barberite..	88.1	5.3	Sn, 4.3; Fe, 0.4; Si, 1.6
Benedict Metal Sheet, Tubes Be-r......................	86–84	14–16	
Berthier's Alloy.....................................	68.	32.	
Blanko-Blech. Cupronil...............................	80.	20.	
Coinage..	75.	25.	
Constantin, Resistance...............................	60.	40.	
Constantin, Resistance...............................	54.	45.	Mn, 1–3; Fe, 0–1
Crotorite No. 4.....................................	89.5	6.32	Al, 3.1; Mn, 0.62; Fe, 0.56

COPPER-NICKEL ALLOYS (*Continued*)

	Cu	Ni	Other Elements and Comments
Cupro-nickel, Sheet	81–79	19–21	
Davis Metal	67.	29.	Fe, 2; Mn, 1.5
Driving Bands, Sheet	95.	5.	
Everbrite	Bal.	35.	Mn, 2.5
Hastelloy D	3.	90.	Si, Bal.; Al, 1.3
Imperial Metal	80.	20.	
Ingots for Nickel Silver	50.	50.	
Lechesne Alloy	90–60	10–40	Al, 0.05–0.2
Locomotive Tubes	97.	3.	
Melchoir Wire	57.3	41.6	Mn, 1.1
Minargent	56.8	40.	W, 2.8; Al, 0.4
"Mond Seventy"	26.	70.	Mn, 4
Monel Metal, cast	28.	68.	Fe, 2.; Si, 1.; Mn, 0.25
Monel Metal, forged	28.	68.	Fe, 2; Mn, 1.5; Si, 0.20
Mumetal	5.3	74.	Fe, 20; Mn, 0.7
Newloy	64.	35.	Sn, 1
Ni-Al Bronze	88.	10.	Al, 2
Nico Metal	90.	10.	
Nu-Bronze	95.4	3.25	Mn, 0.25; Si, 0.73
Platnam	33.	54.	Sn, 13; Fe, 0.5; Al, 0.3
Rakel's Alloy	88.	10.	Zn, 1; Mn, 1
Sheathing Bronze	45.	32.5	Sn, 16; Zn, 5.5; Bi, 1.5
Silveroid	54.	45.	Mn, 1
Turbine Blading	82.1	14.7	Al, 2.5; Zn, 0.7; Si, 0.04
Turbine Material	79–81	21–19	Fe, 0.75 max.
Watch Alloy	50.	47.2	Cd, 2.8
White Ni Alloy	65.	32.25	Al, 2.75

PHYSICAL PROPERTIES OF NICKEL ALLOYS

		Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness
A. Ni, 99.18; Mn, 0.5; Fe, 0.4; Cu, 0.16; C, 0.1	Hot Rolled	77 200	33 400	43.7	59.5	67.
	Annealed	76 850	26 750	48.5	75.9	60.5
E. Ni, 97.22; Mn, 1.89; Fe, 0.52; Cu 0.18; C, 0.11	Hot Rolled	81 800	34 350	45.6	63.5	69.
	Annealed	80 700	27 500	49.7	74.2	63.
D. Ni, 94.44; Mn, 4.63; Fe, 0.56; Cu, 0.18; C, 0.11	Hot Rolled	86 500	38 550	39.7	52.6	77.
	Annealed	85 800	32 650	48.9	72.4	68.
Navy. Copper-Nickel rods, etc. (46 M 7 d)						
Cu, 23; Ni, 60; max. Fe, 3.5; Mn, 3.5; Al, 0.5; Si, 0.5; C, 0.3	up to $\frac{1}{4}$ in. in diameter	75 000	30 000	30.	....	.....
	$\frac{1}{4}$ to 1 in. in diameter	80 000	40 000	30.	....	.....
	1 to 2 in. in diameter.	85 000	48 000	30.	....	.....
	2 to 3$\frac{1}{2}$ in. in diameter	80 000	35 000	35.	....	.....
Navy. Copper-Nickel Castings. (46 M 1 d) Same analysis. C + Si, 2.0, maximum		65 000	32 000	25.	....	.....
Monel Metal	Cast	65 000 to 80 000	30 000 to 40 000	25 to 35	....	100 to 120
	Hot Rolled	85 000	45 000	40.	60.	150
	Cold Rolled	80 000 to 110 000	60 000 to 90 000	20 to 30	....	180 to 200
	Rod, cold drawn	100 000	70 000	20.	50.	170
	Wire, hard	100 000 to 120 000	90 000 to 110 000	1 to 2	....	.....
	Sheet, hard	130 000	100 000	....	....	200
	Wire, annealed	65 000 to 75 000	25 000 to 35 000	20 to 30	....	.....
	Sheet, annealed	70 000	30 000	....	....	125

PHYSICAL PROPERTIES OF NICKEL ALLOYS (*Continued*)

		Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness
Modified Monel	at 70° F.	70 000	43 000	5 to 7	4	.....
Ni, 60–65; Cu, 27–24; Sn, 9–11; Si,	at 600° F.	68 000	46 000	2 to 5	3.5	.....
Fe, Mn, 1–3	at 900° F.	60 000	44 000	2 to 5	3.5	.....
Ni, 44.8; Cu, 53.8; Mn, 1; Fe, 0.27;	Hot Rolled	67 750	35 000	42.5	76.5	.....
C, 0.05	Annealed	66 600	27 000	46.	47.9	.....

COPPER, NICKEL, ZINC ALLOYS

(Agiroide, Alfenide, Argentan, Arguzoid, Argyrolith, Electrum, Neusilber, Nickelin, Nickel Silver Maillechort, Paktong, Sterlin, Tutenag, White Copper, etc.)

	Cu	Zn	Ni	Fe	Sn	Pb	Other Elements and Comments
Albatra Metal	57.5	22.5	18.75	....	....	1.25	
Alpakka	63.94	19.24	14.55	0.4	0.12	0.03	Ag, 2.02
Aluminum Silver	57.	20.	20.	....	....	....	Al, 3.0
Ambrac A	74.5	5.0	20.0	....	....	....	Mn, 0.50
Ambrac B	64.5	5.0	30.0	....	....	....	Mn, 0.50
American Silver, cast	49.36	20.7	24.2	1.3	0.45	....	Mn, 3.83; Al, 0.13
American Silver, cast	57.7	24.2	15.3	0.6	0.69	1.5	
American Silver, cast	59.11	22.66	11.22	....	....	2.9	Al, 1.5; P Sn, 5.0
Aphit	70.	5.5	20.	....	....	....	Cd, 4.5
Aphit	75.1	2.37	20.75	....	....	....	Cd, 1.8
Argentan:							
Sheet	40–65	17–32	15–30	....	....	....	
Chinese	40.4	25.4	31.6	2.6	....	....	
French	50.32	30.94	18.4	....	....	....	
Berlin	55.5	29.1	15.5	....	....	....	
Vienna	55.6	21.8	22.2	0.38	....	....	
English	63.36	17.01	19.13	0.38	....	...	
Russian	63.88	17.58	17.58	0.33	....	0.32	
Castings, Berlin	48.32	23.8	24.15	3.61	....	....	
Castings, Russian	57.52	18.94	20.35	3.15	....	....	
Solder	35.	57.	8.	....	....	....	
Argoid Metal	52.6	25.8	21.6	....	....	....	
Argozil	54.	28.	14.	....	2.	2.	
Arguzoid	55.78	23.2	13.4	....	4.03	3.54	
Aterite, Cast	66.75	17.25	13.92	1.58	....	0.18	Mn, 0.23; Al, 0.17
Aterite, Rolled	67.76	19.97	12.36	1.51	....	0.07	Mn, 0.16
Aterite, Rolled	46.96	38.	10.82	1.9	....	....	Mn, 2.24
Back Case Metal	62.	20.	18.	....	....	....	
Baudrins Alloy	72.	7.1	17.	....	2.5	....	Co, 1.8; Al, 0.5
Benedict Plate	57.	28.	15.	....	....	....	
Benedict Metal	50.	35.	15.	....	....	....	
Bismuth Brass	47.	21.	30.9	....	1.	....	Bi, 0.1
Bismuth Brass	52.	12.	30.	....	....	5.	Bi, 1.
Bismuth Bronze	45.	21.5	32.5	....	....	....	Bi, 1.
Bismuth Bronze	53.	20.	10.	....	15.	....	Bi, 1.; Al, 1
Bolster Silver	65.5	16.	18.	....	....	0.5	
Brazing Solder	35.	57.	8.	....	....	....	
Brazing Solder	45.	45.	10.	....	....	....	
Carbondale	66.	16.	18.	....	....	....	
Casting	55.8	23.3	13.4	....	4.	3.5	
Casting	69.9	5.6	19.8	....	....	....	Cd, 4.7
Cataract Metal	54.5	18.5	19.2	1.6	0.6	5.4	Mn, 0.1
China Silver	58.	17.5	11.5	....	....	....	Ag, 2

COPPER, NICKEL, ZINC ALLOYS (*Continued*)

	Cu	Zn	Ni	Fe	Sn	Pb	Other Elements and Comments
Christofle Metal	(Silver-plated German Silver)						Ag, 2.0
Chromax Bronze	66.7	12.1	15.2	....	....	....	Al, 3.; Cr, 3
Clark's Alloy	75.	7.2	14.	....	1.9	....	Co, 1.9
Colorado Metal	57.	18.	25.	....	....	....	
Craig Gold	80.	10.	10.	....	....	....	
Cupping and Milling	58.	21.5	20.	....	....	0.5	
Decobra	74.4	5.4	19.	0.8	....	....	Mn, 0.4
Dienett's Silver	51.	32.	6.4	....	1.	9.5	
Drawing and Spinning	58.66	29.33	12.	....	....	....	
English	61.3	19.1	19.1	....	....	....	
Eighteen Per Cent	65.	17.	18.	....	....	....	
Electrum	51.61	22.58	25.81	....	....	....	
Esthonia, 5 Mark	70.	20.	10.	....	....	....	
Everbrite Metal	59.8	4.2	24.9	0.8	5.6	4.5	
Fifteen Per Cent	56.66	28.33	15.	....	....	....	
Fourteen Per Cent	60.	26.	14.	....	....	....	
Fourteen Per Cent	58.	28.	14.	....	....	....	
Flat Ware Stock	53.	26.	21.	....	....	....	
Frick's Alloys	55–50	31–30	19–17	....	....	....	
Bluish-Yellow, Hard	55.50	39.00	5.50	....	....	....	
Pale Yellow, Ductile	62.50	31.20	6.30	....	....	....	
Fricke's Silvery	50.00	18.80	31.20	....	....	....	
Fricke's Harder	69.00	30.00	10.00	....	....	....	
German Silvers:							
Best	46.	34.	20.	....	....	....	
Common Formula	55.	25.	20.	....	....	....	
Austrian Tableware (Gersdorf)	50.00	25.00	25.00	....	....	....	
Austrian Tableware (Gersdorf)	55.60	22.20	22.20	....	....	....	
Austrian Malleable (Gersdorf)	60.00	20.00	20.00	....	....	....	
Berlin Alloy	54.	28.	18.	....	....	....	
Richest	52.00	26.00	22.00	....	....	....	
Medium	59.00	30.00	11.00	....	....	....	
Lowest	63.00	31.00	6.00	....	....	....	
Birmingham (Hiorns):							
Extra White Metal	50.	20.	30.	....	....	....	
White Metal	54.	22.	24.	....	....	....	
Arguzoid	48.5	31.	20.5	....	....	....	
Best Best	50.	29.	21.	....	....	....	
Special Firsts	56.	27.	17.	....	....	....	
First Bests	56.	28.	16.	....	....	....	
Seconds	62.	24.	14.	....	....	....	
Thirds	56.	32.	12.	....	....	....	
Special Thirds	56.5	32.5	11.	....	....	....	
Fourths	55.	35.	10.	....	....	....	
Fifths, for Plate	57.	36.	7.	....	....	....	
French Alloy (Arcet)	50.00	31.30	18.70	....	....	....	
French Alloy (Arcet)	50.00	30.00	20.00	....	....	....	
French Alloy (Chaval)	58.30	25.00	16.70	....	....	....	
Russian	56.2	23.36	20.4	....	....	....	
Russian	51.4	22.32	26.22	....	....	....	
Russian	46.1	18.	35.8	....	....	....	
Sheffield:							
Common, Yellow	59.30	25.90	14.80	....	....	....	
Silver, White	55.20	24.10	20.70	....	....	....	
Electrum, Bluish	51.60	22.60	25.80	....	....	....	
Hard Alloy	45.70	20.00	31.30	....	....	....	

COPPER, NICKEL, ZINC ALLOYS (*Continued*)

	CU	ZN	NI	FE	SN	PB	OTHER ELEMENTS AND COMMENTS
Keene's Alloy	75.	2.3	16.	1.5	2.8	....	Co, 2; Al, 0.5
Key Stock	60.	26.	12.	....	....	2.	
Key Stock	65.	22.	12.	....	....	1.	
Knife Bolsters	68.	16.50	15.	....	....	0.5	
Knife Bolsters	56.	28.	16	....	....	....	
Lucetin (Le Mat's)	80.	5.	16.	5.	2.	....	Co, 1.
Maillechort, Paris	66.24	13.42	13.42	3.21	0.22	0.15	
Maillechort, Vienna	66.6	13.6	19.3	0.48	....	....	
Maillechort	65.4	13.4	16.8	3.4	....	....	
Mangan-Neusilber	59.	20.	18.	....	....	....	Mn, 3
Mangan-Neusilber	65.	5.	10.	....	....	....	Mn, 20.
Mangan-Neusilber	77.25	8.75	16.57	....	....	....	Mn, 2.43
Martie's Alloy	Bal.	18.	35.	10.	10.	....	
Meco	50.	20.	25.	....	....	....	
Melchoir Wire	62.7	25.9	10.8	....	....	....	Mn, 0.6
Milling	56.	31.	12.	....	....	1.	
Milling	56.5	28.	15.	....	....	0.5	
Milling	56.	27.5	16.	....	....	0.5	
Milling	54.	27.5	18.	....	....	0.5	
Naubuc Knife Stock	58.	16.25	25.	0.75	....	....	
Neogen	58.0	27.	12.	....	2.	....	Bi, 0.5; Al, 0.5
Niag	46.7	40.7	9.1	....	....	2.8	Mn, 0.3
Nickel Bronze	60.	12.	20.	....	8.	....	
Nickel Bronze	47.	....	3.	....	10.	....	PSn, 1.0
Nickel Bronze	47.	21.	30.9	....	1.	....	Bi, 0.1
Nickel Bronze	50.	18.	12.	....	2.	18.	
Nickel Bronze	61.5	10.95	15.35	....	1.88	10.15	
Nickel Brass	50.00	34.9	15.	....	....	....	Al, 0.1
Nickel Bearing	50.	....	25.	....	25.	....	
Nickelin	55.3	13.1	31.07	0.43	....	0.18	
Nickeline	75–55	0–20	18–32	....	....	....	
Nickeline	55.	21.	13.	....	2.	10.	
Nickel Oreide	65.50	32.66	2.	....	....	....	
Nickel Oreide	64.	32.	4.	....	....	....	
Nickel Oreide	63.33	31.66	5.	....	....	....	
Nickel Oreide	86.66	6.66	6.66	....	....	....	
Nickel Oreide	63.33	30.66	6.	....	....	....	
Optical Wire	54.	28.	18.	....	....	....	
Optical Wire	55.	27.	18.	....	....	....	
Paktong: Pai-t'ung or White Copper:							
Fyfe (1822)	40.4	25.4	31.6	2.6	....	....	
Peat (1923), dark	57.9	32.2	7.7	2.5	....	....	
Cookson, Ltd., white	40.9	45.	11.1	2.5	....	0.23	Co, 0.16
Keferstein	26.3	36.8	36.8	....	....	....	
Thurston (Fyfe)	43.8	40.6	15.6	....	....	....	
Tutenag	45.7	39.6	17.4	....	....	....	
Tutenag (?)	44.	16.	40.	....	....	....	
Pai-t'ung—white copper	26–40	41–32	16–37	0–2.6	....	....	
Packing Metal	51.8	14.3	15.	....	1.8	17.	
Parker's Chrome Alloy	60.	20.	10.	....	....	....	Cr, 10
Platinoid	54.00	20.40	24.77	0.47	....	0.15	Mn, 15.
Platinoid	60.	24.	14.	....	....	....	W, 1–2
Platinoid	62.	22.	15.	....	....	....	
Platinoid Solder	47.	42.	11.	....	....	....	
Plumber's White	58.	25.	15.	1.	....	1.	Mn, 0.3
Pope's Island Alloy	70.	15.	14.	....	....	....	
Resistance Wire	56.50	25.50	18.	....	....	....	
Rheotan	52.	18.	25.	5.	....	....	
Rolling	49.	39.	12.	....	....	....	
Scovill Leaded Rod	46.	Bal.	10.	....	....	2.5	

COPPER, NICKEL, ZINC ALLOYS (*Continued*)

	CU	ZN	NI	FE	SN	PB	OTHER ELEMENTS AND COMMENTS
Seawater Bronze	45.	5.5	32.5	....	16.	....	Bi, 1.
Show-case Metal	58.	24.	18.	....	....	....	
Show-case Metal	59.50	22.50	18.	....	....	....	
Sheffield	57.	24.	19.	....	....	....	
Sheffield	63.34	17.01	19.13	....	....	....	
Sheffield	62.63	26.65	10.85	....	....	0.2	
Sheffield	54.7	37.2	17.1	....	....	....	
Sheffield	57.4	26.5	13.0	....	....	3.0	
Silvel, Cast	67.93	15.84	6.52	2.22	....	0.48	Mn, 6.8; Al, 0.13
Silverine	80–71	1–8	16–17	1–1.5	1–2.8	....	Co, 1–2
Silver Metal	53.3	8.3	31.6	0.8	1.2	3.6	Mn, 0.3
Silvore	61.9	19.5	18.4	0.3	....	....	
Smitter-Lenian	72.	9.75	12.75	2.	2.25	....	Bi, 1.
Solders	45–35	45–75	8–10	....	....	....	
Solders, white	45.	45.	10.	....	....	....	
Spinning Silver	67.	17.	16.	....	....	....	
Spoons, Forks, etc	60.	22.	18.	....	....	....	
Spring Silver	54.6	27.3	18.	....	....	....	
Sterlin	68.52	12.84	17.88	....	....	0.76	
Sterline	68.	13.25	18.	0.75	....	....	
Sterlite	54.3	16.6	27.3	0.6	0.4	0.6	Mn, 0.2
Suhler White Copper	40.4	25.4	31.6	....	....	2.6	
Ten Per Cent	56.	34.	10.	....	....	....	
Ten Per Cent	60.	30.	10.	....	....	....	
Ten Per Cent	62.	28.	10.	....	....	....	
Thirty Per Cent	46.66	23.33	30.	....	....	....	
Thirty Per Cent	54.	16.	30.	....	....	....	
Toucas	35.75	7.14	28.56	7.14	7.14	7.14	Sb, 7.13
Tuc-Tur, Rod	61.2	20.9	17.6	0.3	....	....	
Tuc-Tur, Sheet	58.6	28.5	12.5	0.3	....	....	
Tungsten Brass	60.	22.	14.	....	....	....	W, 4.
Turbine Bushing	61.5	10.95	15.35	....	1.9	10.15	
Turning	58.50	29.00	12.00	....	....	0–5	
Turning	65.	22.	12.	....	....	1.	
Tutenag (Tooth and Egg Metal) is wrongly used for Paktong. It was originally used for Spelter in the China and India trade.							
Twelve Per Cent	58.6	29.3	12.	....	....	....	
Twenty Per Cent	53.33	26.66	20.	....	....	....	
Twenty Per Cent	57.	23.	20.	....	....	....	
Twenty Per Cent	62.	18.	20.	....	....	....	
Twenty Per Cent	64.	16.	20.	....	....	....	
Twenty-one Per Cent	57.	22.	21.	....	....	....	
Twenty-one Per Cent	59.	20.	21.	....	....	....	
Victor Metal	49.94	34.27	15.4	0.28	....	....	Al, 0.11
Viennese Ornaments	55.	25.	20.	....	....	....	
Viennese Sheet	60.	20.	20.	....	....	....	
Viennese Tableware	50.	25.	25.	....	....	....	
Wagner's Formula	50–66	19–31	13–18	....	....	....	
Watch-case Bezels	60.	24.	16.	....	....	....	
Watch-case Bezels	63.	21.	16.	....	....	....	
Watch-case Metal	55–65	30–16	10–28	....	....	0–1	
Wessels Silver	51.	17.	32.	....	....	....	
Wessels Silver	66–51	12–17	19–32	0–0.5	....	....	Ag, 0–2
White Alloy	48.8	24.4	24.4	2.4	....	....	
White Alloy	53.0	23.0	22.0	2.0	....	....	
White Benedict	60.4	18.1	16.4	....	0.7	4.4	
White Copper	70.	18.	12.	....	....	....	

PHYSICAL PROPERTIES OF ALLOYS FROM AMERICAN BRASS CO. SPECIFICATIONS

Material	Form	Approximate Composition, per cent			Tensile Strength, lb. per sq. in.		Yield Point, lb. per sq. in.		Elongation in 2 in., per cent		Brinell Hardness	
		Cu	Zn	Ni	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Ambrac A	Sheet	75.0	5.0	20.0	85 000	50 000	77 000	23 000	5.0	35.0	100	71
	Rod	75.0	5.0	20.0	80 000	55 000	70 000	18 000	10.0	50.0	...	..
	Wire	75.0	5.0	20.0	115 000	55 000	......	......	2.0[a]	30.0[a]	...	..
Ambrac B	Sheet	65.0	5.0	30.0	120 000	65 000	......	......	2.0	30.0	190	90
	Rod	65.0	5.0	30.0	80 000	......	......	......	10.0	.....	...	..
	Wire	65.0	5.0	30.0	130 000	......	......	......	2.0[a]	.....	...	..
18 per cent Nickel Alloy	Sheet	65.0	17.0	18.0	90 000	58 000	83 000	......	4.0	40.0	158	77
18 per cent Nickel Alloy	Sheet	55.0	27.0	18.0	110 000	60 000	......	......	1.0	40.0	...	..
	Wire	55.0	27.0	18.0	143 000	60 000	......	......	1.0[a]	40.0[a]	...	..
15 per cent Nickel Alloy	Sheet	64.0	21.0	15.0	93 000	58 000	......	......	5.5	40.0	...	73
15 per cent Nickel Alloy	Sheet	57.0	28.0	15.0	95 000	55 000	......	......	2.0	35.0	...	74
10 per cent Nickel Alloy	Sheet	65.0	25.0	10.0	90 000	50 000	......	......	3.0	45.0	...	82

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[a] Elongation in 10 in. for diameter over 0.206 in.

Scovill Leaded Rod.

Cu, 46; Ni, 10; Zn, 41.50; Pb, 2.50.

Soft, Tens. Str., 65,000 lb. per sq. in.; Yield Point, 30,000 lb. per sq. in.; Elongation in 2 in., 35 per cent.

4 hard, Tens. Str., 132,000 lb. per sq. in.; Elongation in 2 in, 3 per cent; Reduction of Area, 25 per cent.

ALUMINUM BRONZES, ETC.

	Cu	Al	Fe	Zn	Ni	Other Elements and Comments
Aircraft	Bal.	10–11.5	4–6	....	4-6	
Alcumite	87–90	6–7	3–4	....	....	Mn. 1-2
Alcumite	87.4	8.4	4.1	....	....	
Alcumite	89.	6.5	3.5	....	1.	
Alcumite	87.5	7.5	3.3	....	1.7	
Aluminum Brass	63.	3.33	....	33.66	....	
Aluminum Brass	67–71	1.25–3.5	....	31.75–25.5	....	
Aluminum Bronze, Percy	90.	10.	....	....	....	
Aluminum Bronze, Percy	86–89	12.5–7.5	....	....	....	Mn, 0.5–1.5; Pb, 1–2
Aluminum Bronze	87.5	4.1	1.7	6.6	....	
Aluminum Silver	57.	3.	....	20.	20.	
Aluminum Iron Bronze H	89.43	6.97	3.41	....	....	
Aluminum Iron Bronze R	85.16	6.6	7.52	....	....	Mn, 0.5
Aluminum Iron Bronze S	85.15	9.43	4.74	....	....	Pb, 0.38; P, 0.09
Aluminum Magnesium Bronze	94.5–89.5	5–10	....	....	....	Mg, 0.5
Aluminum Manganese Bronze	89.12	9.6	....	....	....	Mn, 1.2
Aluminum Nickel Bronze	85.	5–10	....	....	10–5	
Aluminum Tin Bronze	85.5	2.5	....	2.	....	Sn, 10.
Aluminum Titanium Bronze	90–89	9–10	1.0	....	....	Ti, trace
Ampco	Bal.	7–11	1–3	....	....	
Cowles Aluminum Bronze	88.4	9.74	0.43	....	....	Si, 1.36
Cowles "A," Special A	89.	11.	....	....	....	
Cowles A 1, 2, 3	80.	10.	....	....	....	
Cowles B	92.5	7.5	....	....	....	
Cowles C 1	94.5	5.5	....	....	....	
Cowles C 2, 3	95.	5.	....	....	....	
Cowles D	97.5	2.5	....	....	....	
Cowles E	98.75	1.25	....	....	....	
Crotorite No. 4	89.5	3.1	0.56	....	6.32	Mn, 0.62
Cupror	94.2	5.8	....	....	....	
Danish Mint	92.	6.	....	....	2.	
Dirigold	(See Oranium Bronze)					

ALUMINUM BRONZES, ETC. (*Continued*)

	Cu	Al	Fe	Zn	Ni	Other Elements and Comments
Dirigold	88.	9.1	....	....	1.1	Sn, 1.7
Dirigold	88.	10.	....	....	2.	
"Double" Bronze (wire)	Bal.	6.5	....	....	....	Skin of pure Cu.
Emperor Brass	60.	20.	....	20.	....	
French (Fe Ni Mn)	81.5	7.	4.	....	5.5	Mn, 2
Hercules Metal	85.5	2.5	....	2.	....	Sn, 10.
Hercules Metal	54.	2.5	7.5	36.	....	
Heusler's Alloy	66.5	11.1	....	....	....	Mn, 22.4
Heusler's Alloy	68.	10.	....	....	....	Mn, 18.; Pb, 4.
Heusler's Alloy, Max	61.	13.	....	....	....	Mn, 26.
Imita Gold	89.	10.3	0.33	....	0.25	Sn, 0.23; Mn, 0.2
Immadium Bronze	(Manganese Bronze with Aluminum)					
Litnum Bronze	89.3	7.3	3.4	....	....	
Lumen Alloy, 27	79.75	10.75	6.	....	....	Mn, 3.5
Lumen Alloy, 193	79.	11.	5.	....	5.	Brinell Hardness 200; Heat treated.
Lynux	89.1	3.75	7.25	....	....	
Metaline	30.	25.	10.	....	....	Co, 35.
Navy	88.5–87	7–9	2.5–4.5	....	....	
Nurnberg Gold	90.	7.5	....	....	....	Au, 2.5
Oranium Bronze S	97.	3.	....	....	....	
Oranium Bronze M	95.	5.	....	....	....	
Oranium Bronze MH	91.5	8.5	....	....	....	
Oranium Bronze H	90.	10.	....	....	....	
Oranium Bronze HX	89.	11.	....	....	....	
Oranium Bronze HH	88.5	11.5	....	....	....	
Rakel's Metal	87.5	10.5	....	1.	....	Mn, 1.
Reichs Bronze	85.15	6.6	7.5	....	....	Mn, 0.5
Roberts-Austen (Purple Gold)	....	21.5	....	....	....	Au, 78.5
Rubel Bronze	80.	10.	4.5	....	4.5	Mn, 1
Secretan	91–95	9–5	....	....	....	Mg, 1.5; P, 0.5
Silliman Bronze	86.4	9.7	3.9	....	....	
Special Aluminum Bronze	79.	10.5	3.1	....	3.6	Mn, 1.6; Brinell Hardness, 200; Heat treated.
Special Aluminum Bronze	Bal.	10.7	4.25	....	3.6	Brinell Hardness, 300; Heat treated.
Superbronze	56.8	1.2	1.3	37.5	....	Mn, 3.2
Superbronze	68.9	5.1	2.0	20.9	....	Mn, 3.0
Tensilite	64.	3.1	1.2	29.	....	Mn, 2.5; Sn, 0.2
Tensilite	67.	4.4	....	24.	....	Mn, 3.8
Tetmajer	86.1	10.	0.98	....	....	Si, 2.48
Tetmajer	89.7	7.1	0.72	....	....	Si, 2.72
Tetmajer	93.3	4.6	0.89	....	....	Si, 0.98
Tufstuf	87.6	8.4	2.1	1.2	....	Mn, 0.4
Turbine Blading	79.6	9.8	4.8	....	4.1	Mn, 0.94; Si, 0.14
Typewriter Metal	57.	3.	....	20.	20.	
Vulcan Metal	80.5	11.7	4.4	0.25	1.5	Sn, 0.7; Si, 0.98; Cr, 0.7

PHYSICAL PROPERTIES OF ALUMINUM-BRONZE CASTINGS

A.S.T.M. B 59 – 28. (S.A.E. 68.)

Grade A. Cu, 87–89; Al, 7–9; Fe, 2.5–4; Sn, 0.5, maximum.

Tens. Str., 65,000 lb. per sq. in.; Yield Point, 25,000 lb. per sq. in.; Elongation in 2 in., 20 per cent.

Grade B. Cu, 89.5–90.5; Al, 9.5–10.5; Fe, 1, maximum; Sn, 0.2.

Tens. Str., 65,000 lb. per sq. in.; Yield Point, 25,000 lb. per sq. in.; Elongation in 2 in., 15 per cent.

Heat Treated, Tens. Str., 80,000 lb. per sq. in.; Yield Point, 50,000 lb. per sq. in.; Elongation in 2 in., 4 per cent.

Navy. 46 B 18 C. (Al-c)
Cu. 85–89; Al, 7–9; Fe, 2.5–4.5; Sn, 0.5, maximum.
Tens. Str., 70,000 lb. per sq. in.; Elongation in 2 in., 25 per cent.

Aluminum Bronze, rolled.
Navy. 46 B 17. (Al-r) S.A.E. 69. (Same except Elongations.)
Cu, 85–87; Al, 7–9; Fe, 2.5–4.5; Sn, 0.5 maximum
Up to $\frac{1}{2}$ in., Tens. Str., 80,000 lb. per sq. in.; Yield Point, 40,000 lb. per sq. in.; Elongation, 30 per cent.
$\frac{1}{2}$ to 1 in., Tens. Str., 75,000 lb. per sq. in.; Yield Point, 37,000 lb. per sq. in.; Elongation, 30 per cent.
Over 1 in., Tens. Str., 72,000 lb. per sq. in.; Yield Point, 35,000 lb. per sq. in.; Elongation, 30 per cent.

PHYSICAL PROPERTIES OF ALLOYS FROM AMERICAN BRASS CO.

Material	Form	Approximate Composition, per cent			Tensile Strength, lb. per sq. in		Yield Point, lb. per sq. in.		Elongation in 2 in., per cent		Brinell Hardness	
		Cu	Al	Ni	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
5 per cent Aluminum Bronze	Sheet	95.0	5.0	....	105 000	52 000	......	......	5.0	70.0	166	67
8 per cent Aluminum Bronze	Sheet	92.0	8.0	....	122 000	60 000	60 000	......	4.0	60.0	155	60
8 per cent Aluminum Bronze with Iron	Rod	85.5	8.0	Fe 2.50	125 000	72 000	80 000	35 000	5.0	50.0	190	70
10 per cent Aluminum Bronze	Rod	90.0	10.0	....	125 000[a]	78 000	67 000	41 000	5.0[a]	36.0	170	100

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[a] Cold worked and heat treated.

FROM BELL TELEPHONE LABORATORIES, INC.

	Approximate Composition, per cent						Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation, per cent
	Cu	Al	Fe	Zn	Ni	Mn			
Alcumite	87.5	7.5	3.3	....	1.7	...	75 000	......	30.0
Hytenal Bronze	60.0	10.0	6.0	19.0	...	5.0	105 000	65 000	20.0
Resistal	90.0	9.0	1.0	....	...	...	75 000	37 000	20.0

Alloys Research Committee:

			Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent
Aluminum Bronze.	Al, 9.9..	Sand Cast...	71 000	25 300	22	....
		Chill Cast...	82 700	27 000	30.5	....
		Rolled $\frac{13}{16}$ in.	85 400	33 200	28.8	30.8
		Cold Drawn.	98 500	90 500	13.0	22.2
Aluminum Bronze.	Al, 10.78	Sand Cast...	66 100	31 600	9.0	....
		Chill Cast...	82 300	37 900	9.0	....
		Rolled $\frac{13}{16}$ in.	86 500	34 500	14.0	18.6

COPPER-MANGANESE ALLOYS

	Cu	Mn	Fe	Zn	Sn	Ni	Other Elements and Comments
Crotorite	70.	30.	2.	....	....	....	
Cupro-Manganese	90.	10.	0.	....	....	....	
Heckman Copper	86.1	12.3	....	0.3	....	0.8	
Heusler's Magnetic Alloys	70.	30.	....	....	....	....	Al, 8–14.5
Heusler's Magnetic Alloy, max	61.	26.	....	....	....	....	Al, 13.
Heusler's Magnetic Alloy	66.5	22.4	....	....	....	....	Al, 11.1
Heusler's Magnetic Alloy	68.	18.	....	....	....	....	Al, 10.; Pb, 4.

COPPER-MANGANESE ALLOYS (*Continued*)

	Cu	Mn	Fe	Zn	Sn	Ni	Other Elements and Comments
High Manganese Brass:							
Ponsard's	50.	24.	16.	10.	....	....	
Ponsard's	60.	25.	....	15.	....	....	
Ponsard's	75.	20.	....	5.	....	....	
Cowles	67.5	18.	....	13.	....	....	Al, 1.; Si, 0.5
Cowles	75.5	16.5	....	8.	....	....	
Cowles	80.	15.	....	5.	....	....	
Rheotan	84.	12.	....	4.	....	....	
Manganese Brass	54.2	4.4	2.4	38.2	....	0.5	
Manganese Brass	55.	4.3	0.7	39.5	....	....	Al, 0.5
Manganese Brass	51.15	4.15	2.25	40.	....	2.2	Al, 0.25
Manganese Brass	53.51	3.24	1.44	38.28	1.22	2.14	
Manganese Brass	55.4	3.2	1.06	39.9	....	....	Al, 0.2
Manganese Brass	60.15	2.34	1.19	34.9	0.94	....	Al, 0.23; Pb, 0.39
Manganese Brass	53.4	1.7	0.	39.	2.66	2.5	Al, 0.2
Manganese Brass	53.5	1.53	2.78	39.	....	2.53	
Manganese Brass	69.5	1.0	....	29.5	....	....	
Manganese Bronze	82.4	0.6	....	....	17.	....	
Manganese Bronze	85.75	0.25	....	....	14.	....	
Manganese Bronze	86.3	2.7	....	5.	6.	....	
Manganese Copper	29.2	51.65	9.68	....	....	....	Al, 6.25; C, 3.23
Manganese Copper	56.3	40.9	1.5	....	....	....	Si, 1.1
Manganese Copper	75.	25.	....	....	....	....	
Manganese Copper	75.3	22.4	2.15	....	....	....	
Manganese Copper	85.	10.92	1.83	2.0	....	....	C, 0.26
Manganese Copper	85.55	10.66	2.66	....	0.39	....	Pb, 0.45
Manganese Copper	84.33	10.61	2.31	2.1	0.4	....	Pb, 0.3
Manganese Copper	89.7	8.72	1.54	....	....	....	
Manganese Nickel	78.3	14.1	....	....	....	7.6	
Manganese Nickel	82.12	15.02	0.6	....	....	2.3	
Manganese Nickel	73.	24.	....	....	....	3.	
Manganese Nickel	70.	25.	....	....	....	5.	
Manganese Nickel	65.	30.	....	....	....	5.	
Manganese Nickel	51.5	31.3	....	....	....	16.2	
Manganese Nickel Silver	72.5	2.43	....	8.75	....	16.57	
Manganese Nickel Silver	65.	20.	....	5.	....	10.	
Manganese Nickel Silver	60.	20.	....	....	10.	10.	
Manganin	86–84	12.	....	....	....	2–4	
Manganin	84.	4.	....	....	....	12.	
Ohmal	87.5	9.	....	....	....	3.5	
Resistance, Lunge	86.5	11.7	1.8	....	....	....	
Resistance, Lunge	84.32	13.45	1.9	....	....	....	
Resistance Metal	85.	12.	3.	....	....	....	
Silvel	73.3	12.	1.8	12.1	....	....	Al, 0.25; Pb, 0.51
Silvel	67.9	6.8	2.22	15.8	....	6.5	Al, 0.13; Pb, 0.48
Therlo	85.	13.	....	....	....	....	Al, 2
Topal	80.	....	....	....	....	....	Fe, Mn, Al, 20
Tubes	96.	4.	....	....	....	....	

COPPER-SILICON ALLOYS

	Cu	Si	Ni	Other Elements and Comments
Barberite	88.1	1.6	5.35	Sn, 4.3; Fe, 0.4
Everdur	95–96	2.75–3.25	....	Mn, 0.75–1.25; Fe, 0.5 max.
Nu-Bronze	95.8	0.73	3.25	Mn, 0.25
Tempaloy I	95.92	0.8	3.	
Tempaloy II	89.28	0.96	5.	Al, 4.74

PHYSICAL PROPERTIES OF COPPER-SILICON ALLOYS FROM AMERICAN BRASS CO.

		Approximate Composition, per cent.					Tensile Strength, lb. per sq. in.		Yield point, lb. per sq. in.		Elongation in 2 in., per cent		Brinell Hardness	
Material	Form	Cu	Si	Mn	Ni	Al	Hard	Soft	Hard	Soft	Hard	Soft	Hard	Soft
Everdur.....	Sheet	96.0	3.0	1.0	...	...	113 000	65 000	75 000	35 000	5.0	48.0	200	70
	Rod	96.0	3.0	1.0	...	...	95 000	55 000	75 000	15 000	15.0	85.0	120	60
	Wire	96.0	3.0	1.0	...	...	145 000	59 000	95 000	25 000	5.0[a]	50.0[a]	....	..
Tempaloy....	Rod	95.0	1.0	...	4.0	...	100 000[b]	45 000	85.000[b]	.....	12.0[b]	25.0	110	60
Tempaloy (A)	Rod	89.2	0.8	...	5.0	5.0	120 000[b]	.....	......	.....	10.0[b]	.....	250[b]	..

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[a] Elongation in 10 in. for diameter over 0.206 in. and in 50 in. for diameter less than 0.204 in.

[b] Cold worked and heat treated.

NOTE.—Figures are averages for "Hard Rolled" or "Drawn" and for "Soft Annealed" material.

ALUMINUM ALLOYS

	Al	Cu	Zn	Mn	Mg	Ni	Fe	Si	Other Elements and Comments
"A Alloy"...........	Bal.	4.7	....	....	1.34	1.85	0.5	0.4	Pb, 1.5
Acieral:									
Sheet.............	Bal.	2.3	....	1.5	0.1	....	1.4	....	
Sheet.............	Bal.	3.7	....	1.0	0.2	....	1.3	....	
Sheet.............	Bal.	3.8	....	1.0	0.5	....	0.7	....	
Cast..............	Bal.	6.4	0.4	....	....	0.90	0.1	0.4	
Cast..............	91.87	5.7	....	....	0.12	0.98	0.94	0.39	
Acieral..............	Bal.	6.	....	....	....	1.	1.25	....	
Aerolite..............	Bal.	1.2	....	....	0.4	....	1.	0.5	
Aerolite Pistons......	86.	12.	....	2.	....	....	....	....	
Aero Metal:									
Sheet.............	Bal.	0.6	....	0.14	2.1	....	1.3	....	
Sheet.............	Bal.	0.2	....	....	2.9	....	0.3	0.4	
Cast..............	Bal.	4.2	27.8	....	....	....	0.5	0.5	
Aero Metal..........	94.2	0.13	....	....	3.1	0.16	1.4	0.58	Sn, 0.42
Aero Metal..........	85.4	6.2	5.3	0.1	....	0.12	1.	0.47	Sn, 1.45
Aeromin.............	Bal.	....	....	....	6.2	....	0.8	0.3	
Aeron...............	Bal.	1.5–2	....	0.75	....	....	....	1.	(Q. 500° C. Aged 100–120° C.)
Air Service (Daniels) 1.	92.	8.	....	....	....	....	....	....	General castings
Air Service (Daniels) 2.	88.5	10.	....	....	0.25	....	1.25	....	Elevated temperatures
Air Service (Daniels) 3.	95.75	2.5	....	....	0.5	....	1.25	....	Strong, ductile castings
Air Service (Daniels) 4.	94.	5.	....	....	....	....	....	1.	Heat treated. For stressed parts
Air Serivce (Daniels) 5.	93.	4.	....	....	....	....	....	3.	Complicated castings
Air Service (Daniels) 6.	92.5	4.	....	....	1.5	2.	....	....	Elevated temperatures
Alclad is **Dural**, Lautal or Aludur with a skin of pure Aluminum.									
Aldrey (wire).........	Bal.	....	....	....	0.4	....	0.3	0.5–0.6	(Q. ingot; drawn down; aged at 150° C.)
Alferium (Schneider) Dural type.									
Almelec(**for conductors**)	98.5	....	....	....	1.2	....	....	1.2	Heat treated
Alneon (Strasser).....	70–90	2–3	22–7	....	....	....	....	....	0.7–1. other ingredients
Alpax or Silumin......	Bal.	0.15	0.2	0.25	....	....	0.8	12–13	
Aludur..............	Bal.	....	....	....	0.45–0.8	....	....	0.6–1.2	
Aluman..............	88.	2.	10.	....	....	....	....	....	
Aluminite Cast.......	Bal.	2.7	23.3	....	....	....	0.4	0.2	
Aluminum Silver......	95.00	....	....	....	....	....	....	....	Ag, 5.

ALUMINUM ALLOYS (*Continued*)

	AL	CU	ZN	MN	MG	NI	FE	SI	OTHER ELEMENTS AND COMMENTS
Alunite	98.6	0.1	....	0.5	....	....	0.6	0.2	
Alzene	66.6	....	33.3	....	....	....	....	....	
Argilite	90.	6.	....	....	....	....	....	2.	Bi, 2
Bell Metal	83.00	....	....	10.	....	....	....	....	Cd, 7.
Bersch Bearing	93.	....	....	....	....	7.	....	....	
Bourbonnes	48.8	0.25	....	....	....	....	0.33	....	Sn, 50.48
Constructal 2	....	....	....	....	....	....	....	....	Contains Mg, Si, Cu and Ti
Constructal 8	Bal.	....	5.	....	1.25	....	....	0.75	Contains $MgZn_2$
Duralumin	Bal.	3.5 5.5	....	0.5 0.8	0.5	....	....	....	
Duralumin	Bal.	4.2	....	0.49	0.76	....	0.67	0.34	
Dural (Anderson)	91.76	6.05	....	0.63	0.46	....	0.79	0.2	Cr, 0.11
Dural (Anderson) (low Copper)	93.97	4.03	....	0.59	0.45	....	0.80	0.2	Cr, 0.10
Durand's	66.6	....	33.3	....	....	....	....	....	
Die Casting	92. 82.	8. 18.	....	....	....	....	....	....	
Die Casting	86.13	10.17	0.24	0.03	0.32	....	2.81	0.3	
Fletcher and Emperer Bearing	92.2	7.5	....	....	....	....	....	....	Sn, 0.25
Fletcher's Alloy	95.5	3.	....	....	....	....	....	....	Sn, 1.; Sb, 0.5; PSn, 5
Frary	Bal.	4.	....	0.6–1	0.3–1	....	....	....	Ca, 0.3–0.6
Haas	Bal.	4.5	....	0.75	....	....	....	1.	Age hardens
Hard Aluminum	77.	....	11.5	....	11.5	....	....	....	
Huron:									
Castings A-5	Bal.	6.6	....	....	0.5	1.25	....	....	Co, 0.25 and (Mn Sn Cd, 0.5)
Rolled A	Bal.	3.5	....	0.6	0.5	....	....	....	Cr, 0.1
Rolled B	Bal.	4.0	....	0.6	0.5	....	....	....	Cr, 0.1
Rolled D	Bal.	4.0	....	....	0.5	....	....	....	Cr, 0.6
Hyblum, rolled	Bal.	0.63	....	....	0.3	1.06	1.	0.27	Cr. Trace
Hyblum	Bal.	0.24	....	0.03	0.02	0.43	0.55	0.19	Cr, 0.07
Ingots:									
Casting 11	88.85	6.6	2.3	1.	....	1.25	....	....	
Casting 12	92.	8.	....	....	....	....	....	....	
Casting 21	90.	10.	....	....	....	....	....	....	
Casting 22	83.7	6.3	5.	....	....	....	....	....	Sn, 5.
Casting 31	80.5	3.	16.	0.5	....	....	....	....	
Casting 32	64.	....	36.	....	....	....	....	....	
Casting 33	81.	....	19.	....	....	....	....	....	
Casting 34	78.	....	22.	....	....	....	....	....	
Rolling 3.5	98.5	....	....	1.5	....	....	....	....	
Rolling 5.5	94.5	2.	2.	1.5	....	....	....	....	
Rolling 8.5	66.6	....	33.3	....	....	....	....	....	
K-Alloy	Bal.	11.3	....	1.1	0.5	....	....	0.79	Heat treated
Koltchougalumin	Similar to Dural.								Small amounts of Cu, Ni, Mn
KS Seewasser	Bal.	....	....	3.	2.5	....	....	....	Sb, 0.5
Krupp (Grosmann) Bearing	87.	8.	....	....	....	....	....	....	Sn, 5.
L-5	Bal.	2.5–3.0	12.5–14.5	....	....	....	....	....	
Lautal	Bal.	4.	....	....	....	....	....	2.	Aged at 120–130° C.
Liberty Piston	76.6	1.06	21.3	....	....	....	0.47	....	Pb, 0.33; Sn, 0.12
Lynite:									
146	Bal.	7.00–8.5	....	....	....	....	....	....	
122	Bal.	9.25–10.75	....	....	....	....	....	....	
109	Bal.	11.5–13.5	....	....	....	....	....	....	
Crank Case	Bal.	7.8	1.5	....	....	....	1.25	....	

ALUMINUM ALLOYS (*Continued*)

	AL	CU	ZN	MN	MG	NI	FE	SI	OTHER ELEMENTS AND COMMENTS
Lynite—***Continued:***									
Body Alloy	Bal.	5.	....	....	....	....	....	....	
Piston	88.5	11.	....	....	0.5	....	....	....	
Piston	95.3	2.14	....	0.07	1.5	....	0.76	0.23	
Mach's	Bal.	....	....	....	2–10	....	....	....	
Magnalium:									
Cast x	Bal.	1.76	....	....	1.6	1.16	....	....	
Cast y	Bal.	1.75	....	....	1.5	....	....	....	Sn and Pb
Cast z	Bal.	0.21	....	....	1.58	....	....	....	Sn, 3.15; Pb, 0.7
Cast	85.00	....	....	....	15.00	....	....	....	
Sheet	95.	....	....	....	5.	....	....	....	
	Bal.	....	1–20	....	1–10	....	....	....	
Magnalite	Bal.	2.	....	....	2.	2.	....	....	
Magnalite	Bal.	2.5	0.5	....	1.3	1.5	....	....	
Magnalite	93.09	2.19	....	....	1.54	1.45	1.10	0.61	
Magnalite	94.27	2.47	0.13	....	1.17	0.65	0.69	0.59	
Magnalite	93.5	2.61	....	....	1.37	1.72	0.86	0.37	Sn, 0.17
Magnalite	93.9	2.4	....	....	1.56	1.19	0.47	....	
Magnalite	93.2	2.44	....	....	1.38	1.25	1.35	0.37	
Maluminum	Bal.	6.4	4.8	0.1	....	....	1.4	0.2	Pb, 0.15
Manhardts	83.33	6.24	....	....	0.05	....	....	....	Sn, 10.; P, 0.07
McAdamite	Bal.	3.1	12–18	....	0.2	....	....	....	
McAdams, W. A.	68.5	7.7	23.1	....	....	0.63	....	....	
McAdams, W. A.	60.	5.	20.	....	....	....	....	....	Ag, 16.5
McAdams, W. A.	70.	3.	26.	....	....	....	....	....	Ag, 1.
McAdams, W. A.	70.	3.	22.	....	....	....	....	....	Sb, 5.
McAdams, W. A.	100.	5.	....	....	....	....	....	....	Ag, 2.
McAdams, W. A.	80.	....	....	....	....	....	....	....	Sn, 8.; Cd, 8.; Ag, 4.
McAdams, W. A.	82.	12.	....	....	....	....	....	....	Cd, 5.; Ag, 1
McKinney:									
Cast	96.	2.	....	1.5	....	....	....	....	
Forging, Hard	94.5	3.	....	2.	....	....	....	....	
Forging, Soft	96.5	2.	....	1.0	....	....	....	....	
McLure	Bal.	8.2	....	0.2	....	....	0.9	0.3	Sn, 5–6
Metalline	25.	30.	....	....	....	....	10.	....	Co, 35.
Meteorite	Bal.	....	1–2	....	....	....	....	....	P, 1–4
Mock Silver	84.2	5.5	....	....	....	....	....	....	Sn, 10.2; P, 0.1
Montegal	....	....	....	....	....	....	....	....	Contains Mg_2Si and $CaSi_2$
Murman's	92.	....	4.4	....	3.6	....	....	....	
Murman's	72.	....	14.5	....	13.5	....	....	....	
Navy	Bal.	1.5	....	0.9	....	0.4	0.4	0.3	
Nelson Bohnalite	88.7	10.4	....	....	....	....	0.63	0.2	
Neonalium (Strasser)	86–94	14–6	....	....	....	....	....	....	0.4–1. other ingredients
Nickeloy	94.	4.2	....	....	....	1.4	....	....	
Page, Dental	93.	2.25	....	....	....	....	....	....	Au, 4.75
Partinium	Bal.	0.64	....	....	....	....	....	....	Sb, 2.4; Sn, 0.16; W, 0.8
Partinium	88.5	7.4	1.7	....	....	....	1.3	1.1	
Pistons	93.3	3.39	....	....	1.39	....	1.46	0.45	
Pistons	93.5	2.45	0.28	....	1.47	1.47	0.4	0.4	
Platinum Substitute	23.6	....	....	....	....	72.	....	....	Bi, 3.7; Au, 0.7
Romanium	Bal.	0.25	....	....	....	1.75	....	....	Sb, 0.25; Sn, 0.15; W, 0.17
Rosein	30.	....	....	....	....	40.	....	....	Sn, 20.; Ag, 10.
Rosenhain and Archutt Forging	72.	3.	25.	....	....	....	....	....	

ALUMINUM ALLOYS (*Continued*)

	AL	CU	ZN	MN	MG	NI	FE	SI	OTHER ELEMENTS AND COMMENTS
Scleron	Bal.	3.	12.	0.6	....	....	0.4	0.5	Li, 0.1 (Q 480° C. Aged R. T.)
Sibley Alloy	67.	....	33.	....	....	....	....	....	
Susini	Bal.	1.5	0.5	1–3	....	....	....	....	
Susini	Bal.	2.5	1.0	1–5	....	....	....	....	
Susini	Bal.	2.5	1.0	1–5	....	....	....	....	
Susini	Bal.	4.5	1.5	2–8	....	....	....	....	
T. Metal	Bal.	0.1	....	....	3.8	....	0.5	0.5	
Tiers Argent	66.	....	....	....	....	....	....	....	Ag, 33.
Verilite	Bal.	2.5	....	0.3	....	....	0.7	0.4	
Verilite	96.	1.	....	0.1	....	1.	....	....	Cr, 1.5
Wolframium	98.	0.36	....	....	....	....	0.22	....	Sb, 1.4; W, 0.05
Wolframium	98.	0.375	....	....	....	....	....	....	Sb, 1.44; Sn, 1; W, 0.04
W. 0.33	Bal.	14.	....	1.	....	....	....	....	
Zeppelin Alloys:									
Rod	94.58	4.16	....	0.62	....	....	0.42	0.52	
Braces	99.1	0.06	0.13	....	....	....	0.38	0.36	
Channels	88.68	0.7	9.1	0.45	....	....	0.43	0.49	Sn, 0.15
Angles	90.27	0.73	7.8	0.27	....	....	0.45	0.37	Sn, 0.11
Zimalium	93.5	....	2.8	....	3.7	....	....	....	
Zimalium	91.	....	4.5	....	4.5	....	....	....	
Zimalium	88.5	....	4.4	....	7.1	....	....	....	
Zimalium	74.	....	14.8	....	11.2	....	....	....	
Zisium	83.	1.	15.	....	....	....	....	....	Sn, 1.
Zisium	82.	3.	15.	....	....	....	....	....	
Ziskon	60.	....	40.	....	....	....	....	....	
Al-Cu, Strongest	Bal.	3.75	....	....	....	....	....	....	
Al-Cu	91.66	7.16	....	....	....	....	0.85	0.33	
Al-Cu	91.62	7.57	0.1	0.07	....	....	0.43	0.22	
Al-Cu-Ni	Bal.	2.	....	....	....	5.25	....	....	
Al-Cu-Ni	Bal.	4.1	....	....	....	1.1	....	....	
Al-Cu-Zn Strong:									
Cast	80.	5.	15.	....	....	....	....	....	
Forged	75.	3.	22.	....	....	....	....	....	
Centrifugal Cast	80.	3.	17.	....	....	....	....	....	
Ingot	82.7	3.15	12.8	0.39	....	....	0.48	0.19	Pb, 0.19; Sn, 0.12
Ingot	82.8	5.52	9.9	0.18	....	....	0.81	....	Pb, 0.3; Sn, 0.27
Casting	83.55	4.87	11.1	0.06	....	....	0.19	0.27	
Al-Cu-Mg Casting	93.6	3.61	....	....	2.23	....	0.31	0.28	
Al-Cu-Mg Casting	93.	3.65	....	....	2.25	....	0.60	0.38	
Al-Cu-Mg Casting	91.9	3.37	....	0.55	3.5	....	0.38	0.29	
Al-Cu-Mg Casting	95.5	4.	....	....	0.5	....	....	....	
Al-Ni-Ti	97.6	....	....	....	....	2.0	....	....	Ti, 0.4
Al-Ni-Zn	85.	....	5.	....	....	10.	....	....	
Va Alloy	80.2	5.01	13.7	....	....	....	0.72	....	V, 0.2
W Alloy	82.1	12.32	4.5	....	....	....	....	....	W, 1.0
Alloys Research Committee:									
"Y" Casting	92.5	4.	....	....	1.5	2.	....	....	
"A" Forging	77.	3.	20.	....	....	....	....	....	
"E" Rolling	76.	2.5	20.	0.5	0.5	....	0.2	0.2	

ALUMINUM ALLOYS FOR PISTONS[1]

Corbin, Al, 87.5; Cu, 12.5
Belgian, Al, 90.5; Cu, 7; Zn, 2.5
German, Al, 93; Mg, 7

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[1] E. V. Pannell, "Aluminum Alloys for Pistons," *The Metal Industry*, Vol. XIX, p. 15 (1921).

ALUMINUM ALLOYS FOR PISTONS (*Continued*)

Curtiss, Al, 95.2; Cu, 2.5; Mg, 1.5
Aerolite, Al, 86; Cu, 12; Mn, 2
British, Al, 88; Cu, 12
British, Al, 85; Cu, 14; Mn, 1
Benz Aviatek, Al, 80; Cu, 6; Zn, 12; Fe, 1.5
British, Al, 94.5; Ni, 5.5
Magnalite, Al, 94.2; Cu, 2.5; Zn, 0.5; Mg, 1.5; Ni, 1.5
Magnalium, Al, 95; Mg, 5
N. P. L. (Y), Al, 92.5; Cu, 4; Mg, 1.5; Ni, 2
Lynite, Al, 88; Cu, 10; Mn, 0.25; Fe, 1.5
Lynite, Al, 90; Cu, 8; Mg, 0.5; Fe, 1.5
Lynite, Al, 88.5; Cu, 10; Mg, 0.5; Fe, 1.0

DIE-CASTINGS

U. S. A. Air Service (1926).
Cu, 3.5–4.5; Si, 4.5–5.5; Tens. Str., 28,000 lb. per sq. in., minimum; Elongation in 2 in., 2.5 per cent, minimum; Brinell Hardness, 60, minimum.

A.S.T.M. Committee B-2.
Compositions Used for Tests.

1. Cu, 4; Fe, 1.5–2
2. Cu, 10; Fe, 1.5–2
3. Cu, 14; Fe, 1.5–2
4. Si, 5; Fe, 1.5–2
5. Si, 13; Fe, 1.5–2
6. Cu, 2; Si, 3; Fe, 1.5–2
7. Cu, 4; Si, 5; Fe, 1.5–2
8. Cu, 1.5; Si, 0.75; Ni, 2.25; Fe, 1.5–2
9. Cu, 4; Si, 1.5; Ni, 4; Fe, 1.5–2
10. Si, 2; Ni, 5; Fe, 1.5–2
11. Cu, 2; Si, 8; Fe, 1.5–2
12. Cu, 8; Si, 1; Fe, 1.5–2

PHYSICAL PROPERTIES OF ALLOYS FROM A.S.T.M. AND OTHER SPECIFICATIONS

B 26 – 30 T. Aluminum-Base Alloy Castings.

Alloy A. Cu, 7–8.5; Fe, 1.2, max.; Si, 0.5, max.; Mn, 0.3 max.; Zn, 0.2, max.; Al, remainder. (S.A.E. 30.)
Tens. Str., 18,000 lb. per sq. in., min.

Alloy B. Cu, 7–8.5; Fe, 0.8–1.4; Si, 1–1.5; Mn, 0.3, max.; Zn, 0.2, max.; Al, remainder.
Tens. Str., 19,000 lb. per sq. in., min.

Alloy C. Cu, 6–8; Fe, 1.5, max.; Si, 1, max.; Zn, 2.5, max.; Al, remainder. (S.A.E. 33.)
Tens. Str., 19,000 lb. per sq. in., min.

Alloy D. Cu, 6–8; Fe, 1.2, max.; Si, 2-3; Zn, 1.5, max.; Al, remainder.
Tens. Str., 18,000 lb. per sq. in., min.

Alloy E. Cu, 11–13; Fe, 1.2, max.; Si, 1, max.; Mn, 0.3, max.; Zn, 0.2, max.; Al, remainder. (S.A.E. 32.)
Tens. Str., 19,000 lb. per sq. in., min.

Alloy F. Cu, 9.25–10.75; Fe, 1.5, max.; Mg, 0.15–0.35; Mn, 0.2, max.; Zn, 0.2, max.; Al, remainder; Fe plus Si, 2, max. (S.A.E. 34.)
Tens. Str., 19,000 lb. per sq. in., min.

Alloy G. Cu, 4–5; Fe, 1.2, max.; Si, 1.2, max.; Mg, 0.3, max.; Mn, 0.3, max.; Zn, 0.2, max.; Al, remainder.
Heat Treatment No. 1; Tens. Str., 28,000 lb. per sq. in., min.; Elongation in 2 in., 6 per cent, min.
Heat Treatment No. 2; Tens. Str., 30,000 lb. per sq. in., min.; Elongation in 2 in., 3 per cent, min.
Heat Treatment No. 3; Tens. Str., 36,000 lb. per sq. in., min.; Elongation in 2 in., 0 per cent, min.

Alloy H. Cu, 3.5–4.5; Fe, 1, max.; Si, 0.7, max.; Mg, 1.2–1.7; Zn, 0.1, max.; Al, remainder; Ni, 1.8–2.3.
Heat Treated; Tens. Str., 32,000 lb. per sq. in., min.

Alloy I. Cu, 0.6, max.; Fe, 1, max.; Si, 4.5–6; Mn, 0.3, max.; Zn, 0.2, max.; Al, remainder. (S.A.E. 35.)
Tens. Str., 16,000 lb. per sq. in., min.; Elongation in 2 in., 3 per cent, min.

Alloy J. Cu, 0.3 max.; Fe, 0.8, max.; Si, 12–13; Mn, 0.5, max.; Zn, 0.2, max.; Al, remainder.
Tens. Str., 24,000 lb. per sq. in., min.; Elongation in 2 in., 5 per cent, min.

Alloy K. Cu, 3–4; Fe, 1, max.; Si, 7–9, Mn, 0.3, max.; Zn, 0.2, max.; Al, 88, min.

S.A.E. 31. Cu, 2.25–3.25; Zn, 12.5–14.5; Si, Fe, Mn, Sn, 1.7, maximum; Al, 81, minimum.
Tens. Str., 25,000 to 30,000 lb. per sq. in.; Elongation in 2 in., 1 per cent plus.

Navy. 46 A 1 a. No. 2 like A.S.T.M. Alloy I. No. 4. Cu, 4–5; Si, 1.2; Fe, 1.2; Zn, 0.25; Mg, 0.35; Heat treated.
Tens. Str., 28,000 lb. per sq. in.; Yield Point, 15,000 lb. per sq. in.; Elongation in 2 in., 6 per cent.

Navy 47 A 3. Sheet.
Cu, 3.5–4.5; Mg, 0.2–0.75; Mn, 0.4–1; Al, 92, minimum.
0.013 to 0.5 in., Annealed, Tens. Str., 35,000 lb. per sq. in.; Elongation in 2 in., 8 to 12 per cent.
0.020 to 0.5 in., Heat Treated, Tens. Str., 50,000 to 55,000 lb. per sq. in.; Yield Point, 25,000 to 30,000 lb. per sq. in.; Elongation in 2 in., 8 to 12 per cent.

Navy 44 A 2. Tubes.
$\frac{1}{4}$ to 1 in. diameter, Heat Treated, Tens. Str., 55,000 lb. per sq. in.; Yield Point, 30,000 lb. per sq. in.; Elongation in 2 in., 18 per cent.

Navy 47 A 4 a.
Mn, 1–1.5; Cu, 0.2; Al, 97, minimum.

	TENSILE STRENGTH, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT
Soft	14 500	20 to 28
Half Hard	19 500	3 to 8
Three-quarter Hard	24 000	1 to 4
Hard	27 000 to 33 000	1 to 4

PHYSICAL PROPERTIES OF ALUMINUM ALLOYS

			TENSILE STRENGTH, LB. PER SQ. IN.	YIELD POINT, LB. PER SQ. IN.	ELONGATION IN 2 IN., PER CENT	BRINELL HARDNESS NUMBER
Cast Alloys:						
No. 100	Al, 99		12 000 to 14 000	4 000	15 to 25	25
No. 106	Mn, 1.5–2.5; Impurities, 1.5, maximum		16 000 to 20 000	......	5	35 to 45
No. 195	Cu, 4–5	Sand Cast, heat treated 4	28 000 to 35 000	13 000	5.5 to 11	70
		Sand Cast, heat treated 16	30 000 to 40 000	21 000	3 to 8	75
		Sand Cast, heat treated 10	36 000 to 50 000	27 000	0 to 5	100
		Permanent Mold, as cast	22 000 to 28 000	....	3 to 6	60 to 70
		Permanent Mold, heat treated 4	35 000 to 39 000	....	5 to 9	70 to 90
		Permanent Mold, heat treated 10	48 000 to 54 500	....	1 to 1.5	110 to 140
No. 196	Cu, 5	Heat Treated	36 000 to 45 000	27 000	0 to 2.5	115
No. 151	Cu, 5.5; Fe, 1; Sn, 1	Permanent Mold	20 500 to 26 500	....	3.5 to 7.5	60 to 70
No. 12	Cu, 7–8.5; Zn, 0.2, maximum; Impurities, 1.7	Sand Cast	18 000 to 23 000	10 000	1 to 3	65
	(S.A.E. 30)	Chill Cast	20 000 to 24 000	10 000	1 to 3	50 to 65
No. 2 L 11	B.E.S. Cu, 6–8; Sn, up to 1	Pistons	20 000 to 29 600	....	4 to 6	...
No. 112	Cu, 6–8; Zn, 1–2.5; Fe, 1–1.5	Sand Cast	19 000 to 24 000	12 000	1 to 2.5	50 to 65
	(S.A.E. 33)	Permanent Mold	21 000 to 29 000	....	1.5 to 3	70 to 90

PHYSICAL PROPERTIES OF ALUMINUM ALLOYS (*Continued*)

		Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Brinell Hardness Number
No. 212	Cu, 7–8.5; Si, 1–1.5; Fe, 0.8–1.2; Impurities, 0.3	19 000 to 24 000	11 000	1 to 2.5	50 to 65
No. 152	Cu, 10 Permanent Mold	20 500 to 29 500	....	1 to 3	85 to 110
No. 122	Cu, 9.25–10.75; Fe, 1.2; Mg, 0.5 Sand Cast, heat treated	35 000 to 40 000	20 000	0 to 1	115
	(S.A.E. 34) Pistons. Permanent Mold, as cast	22 000 to 30 000	....	0 to 1.5	85 to 105
	Permanent Mold, heat treated 12	24 000 to 32 500	....	0.5 to 1	125 to 160
	Permanent Mold, heat treated 7	40 000 to 48 000	....	0.5 to 1	125 to 160
No. 109	Cu, 11.5–13.5 (S.A.E. 32) Pistons Sand Cast	20 000 to 28 000	15 000	0 to 1.5	70
No. 43	Si, 4.5–6; max., Fe, 0.8; Cu, 0.6; Mn, 0.2 Sand Cast	17 000 to 22 000	7 000	3 to 7	35 to 45
	Permanent Mold	18 000 to 24 500	....	3 to 8	40 to 45
No. 45	Si, 9–11; max., Fe, 0.6; Mn, 0.5; Cu, 0.6 Sand Cast	19 000 to 22 000	8 000	1 to 3	40 to 50
	Permanent Mold	24 000 to 29 000	....	4 to 5	45 to 56
No. 47	Si, 12.25–13; max., Fe, 0.6; Cu, 0.15; Mn, 0.25	24 000 to 31 000	11 000	5 to 15	45 to 65
No. 13	Si, 12; Fe, 2 Die Cast	28 000 to 30 000	....	1 to 3	70 to 80
No. 125	Si, 5; Fe, 1; Sn, 2 Permanent Mold	17 000 to 22 500	....	4 to 8	40 to 45
No. 83	Cu, 2.5; Si, 3 Die Cast	25 000 to 28 000	....	3 to 6	55 to 65
No. 85	Cu, 3.5; Si, 5.5 Die Cast	28 000 to 30 000	....	2.5 to 4	60 to 70
No. 73	Cu, 2.5; Si, 8.5 Die Cast	30 000	....	2	80
No. 108	Cu, 4.5; Si, 5.5 Permanent Mold	21 000 to 29 500	....	1 to 4.5	65 to 80
No. 145	Zn, 10–12; Cu, 2.5; Fe, 1.5 Sand Cast	25 000 to 37 000	12 000	3 to 6	65
No. 6	Zn, 12.5–14.5; Cu, 2.5–3; Fe, 0.8, maximum; Si, 0.7—(S.A.E. 31)	25 000 to 30 000	....	1+	...
	B.E.S. 2L 5. Crank Cases, Gear Boxes	31 000 to 36 000	....	6 to 10	...
No. 142	Cu, 4; Ni, 2; Mg, 1.5 Heat Treated	30 000 to 40 000	25 000	0.5 to 2	100+
Y	Cu, 3.5–4.5; Ni, 1.8–3.2; Mg, 1.2–1.7; max., Fe, 0.8; Si, 0.7 Heat Treated	38 000 to 49 000	....	3 to 6	...
	as Cast	20 000 to 24 600	....	1 to 2	...
No. 93	Cu, 4; Ni, 4; Si, 2 Die Cast	28 000	....	0	80
Wrought Alloys:					
No. 2 S	Al, 99; Annealed 650° F. Soft	12 000 to 16 000	....	30 to 45	...
	Half Hard	16 000 to 20 000	....	3 to 7	...
	Hard	22 000[a]	....	1 to 4	...

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[a] Minimum.

PHYSICAL PROPERTIES OF ALUMINUM ALLOYS (*Continued*)

Wrought Alloys (*Continued*):			Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Brinell Hardness Number
No. 3 S	Mn, 1–1.5; Al, 97.1, min. Annealed 800° F	Soft	15 000 to 18 000	....	15 to 30	...
		Half Hard	20 000 to 24 000	....	2 to 6	...
		Hard	27 000[a]	....	1 to 4	...
		Gage 8–32 Soft	18 000 to 20 000	....	16 to 26	32
		Gage 8–32 Hard	31 000 to 47 000	....	1 to 5	62 to 70
Naval Gun Factory.	Cu, 1–2; Mn, 1	Cold Finish (250° C.)	27 500	15 000	12	...
		Hot Finish (525° C.).	21 000	12 000	27	...
A.R.C. (1907).	Cu, 4	Hot rolled, 1.25 in., bar.	63 000	20 000	20	...
		Cold rolled, 0.05 in., sheet	41 000	35 000	4 in 3 in.	...
	Si, 5–7	Hard Rolled	35 000	....	5	...
	Zn, 10–15	Forgings	25 000 to 30 000	....	30	...
A.R.C.—A.	Zn, 20; Cu, 3	Cold Rolled Sheet	65 000	....	..	...
		Cold Rolled, aged 5 years	72 000	....	..	...
No. 17 S	Cu, 3.5–4.5; Mn, 0.4–1; Mg, 0.3–0.75	Annealed 650° F. O.	25 000 to 35 000	7 000 to 10 000	14 to 22	44 to 55
		Quenched 940–960° F., 10–120 hours; aged 200° F., 2 hours. T.	55 000 to 63 000	30 000 to 40 000	18 to 25	90 to 105
No. A 17 S	Cu, 2.5; Mn, 0.3	Annealed 650° F. O.	20 000 to 30 000	....	20 to 28	30 to 40
		Quenched 940–960° F., 25 hours, aged. T.	35 000 to 45 000	15 000 to 20 000	20 to 28	55 to 75
No. B 17 S	Cu, 3.5; Mg, 0.3	Annealed, 650° F. O.	20 000 to 25 000	....	20 to 28	30 to 40
		Quenched 940-960° F., 25 hours aged. T.	42 000 to 50 000	20 000 to 25 000	20 to 28	65 to 85
No. 25 S	Cu, 3.9–5; Mn, 0.5–1.1; Si, 0.5–1.5	Annealed, 650° F. O.	23 000 to 35 000	7 000 to 12 000	12 to 22	45 to 55
		Quenched 960–980° F., 25 hours. W.	45 000 to 53 000	15 000 to 30 000	15 to 20	68 to 85
		Drawn 285–295° F., 8–15 hours. T.	55 000 to 63 000	30 000 to 40 000	16 to 25	90 to 105
No. 25 S	....	Cold Worked	30 000 to 45 000	....	10 to 3	...
		Extruded	30 000 to 40 000	15 000 to 20 000	10 to 18	50 to 65
No. 51 S	Si, 1.2–0.6; Mg, 0.45–0.8; Al, 95.5	Annealed 650° F. O.	14 000 to 19 000	4 000 to 6 000	15 to 30	25 to 32
		Quenched 960-980° F., 25 hours. W.	30 000 to 40 000	15 000 to 20 000	20 to 30	55 to 72
		Drawn 310-320° F., 18 hours. T.	45 000 to 50 000	30 000 to 40 000	10 to 18	90 to 100
		Cold Worked	17 000 to 30 000	....	5 to 15	...
		Extruded	20 000 to 30 000	9 000 to 13 000	18 to 25	40 to 55

---

[a] Minimum.

PHYSICAL PROPERTIES OF ALUMINUM ALLOYS (*Continued*)

			Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation in 2 in., per cent	Brinell Hardness Number
No. C 17 S	**Cu, 4; Si, 1.25; Mn, 0.4; Mg, 0.5**					
	Annealed 650° F.....O.		25 000 to 35 000	7 000 to 10 000	12 to 20	42 to 55
	Quenched 920–940° F., 25 hours; Drawn 310–320° F., 18 hours.....T.		63 000 to 70 000	50 000 to 55 000	8 to 14	95 to 125
	High Silicon Dural: Cu, 4.32, Si, 0.78; Mn, 0.49; Mg, 0.5					
	Quenched 500–515° C....	Aged 3 days.....	59 000	....	25	...
		Aged 70 hours at 120° C....	66 900	....	20.5	...
		Aged 20 hours at 150° C....	75 300	....	13	..
No. 124	Y. Alloy Cu, 4; Ni, 2; Mg, 1.5; Si, 0.3.					
	Quenched 520° C. and aged.....		60 000	35 000	16	...
Scleron:	Cu, 3; Zn, 12; Mn, 0.6; Fe, 0.4; Si, 0.5; Li, 0.1 Quenched 480° C.; aged.....		57 000 to 71 000	....	10 to 15	...
Constructal 8:	Zn, 5; Mg, 1.25: Si, 0.75 Quenched 520° C.; aged.....		52 000	....	19	...
K. S. Seewasser:	Mn, 3; Mg, 2.5; Sb, 0.5.....	Thin Sheet.	67 000 to 74 000	....	15 to 20	...
		Sand Cast..	20 640	12 800	2.5	60
		Chill Cast..	26 760	17 000	3.8	60
		Die Cast...	32 720	....	1.6	81
		Rolled, soft.	20 000 to 38 800	....	9 to 15	39 to 83
		Rolled, hard	20 600 to 45 500	....	46 to 14	39 to 83

PHYSICAL PROPERTIES AT HIGH TEMPERATURES (Jeffries)

Wrought at 205° C.:	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Elongation, per cent	Reduction of Area, per cent
3S. Mn, 1.25.....	5 700	3 400	59.	90.
51S. Aludur.....	32 100	24 000	10.	23.
25S. Lautal.....	29 000	22 000	22.	66.
17S. Dural.....	39 000	27 000	25.	44.
"Y" Alloy.....	44 500	....	...	...
Cast at 260° C.:				
Alpax.....	11 000	5 000	15.	15.
112. Cu, 7.5; Zn, 1.5 (Sand cast)	16 000	11 000	1.	0.
195. Cu 4.5 (Heat treated)....	18 500	12 000	5.	6.
122. Lynite (Chill cast).......	25 500	15 000	3.	0.
"Y" (Sand cast, heat treated).	26 000	19 000	1.	0.

AIRCRAFT ALLOYS (Johnson)

Cu, 10; Fe, 1.25; Mg. 0.25. Quenched 500° C., 4 hours, boiling water. Drawn 205° C. 1 hour.

As cast: Tens. Str., 25,000 lb. per sq. in.; Elongation in 2 in., less than 1 per cent; Brinell Hardness, 85.

Heat treated: Tens. Str., 35,000 lb. per sq. in.; Elongation in 2 in., less than 0.5 per cent; Brinell Hardness, 110.

Pistons. Bearings.

Cu, 4; Ni, 2; Mg, 1.5; Quenched 510° C., 4 hours, boiling water. Drawn 205° C., 1 hour.
As cast: Tens. Str., 25,000 lb. per sq. in.; Elongation in 2 in., 1 per cent; Brinell Hardness, 80.
Heat-treated: Tens. Str., 35,000 lb. per sq. in.; Elongation in 2 in., 0.5 per cent; Brinell Hardness, 100.
Pistons. Air-cooled cylinder heads.

Cu, 2.5; Fe, 1.25; Mg, 0.5. Quenched 510° C., 2 hours, boiling water. Drawn 150° C., 2 hours.
As cast: Tens. Str., 19,000 lb. per sq. in.; Elongation in 2 in., 1.5 per cent; Brinell Hardness, 65.
Heat-treated: Tens. Str., 28,000 lb. per sq. in.; Elongation in 2 in., 3 per cent; Brinell Hardness, 70;
Housings. Brackets.

Cu, 4.5; Si, 1; Quenched 495° C., 24 hours, boiling water. Drawn 150° C., 2 hours.
As cast: Tens. Str., 21,000 lb. per sq. in.; Elongation in 2 in., 2 per cent; Brinell Hardness 60.
Heat-treated: Tens. Str., 30,000 lb. per sq. in.; Elongation in 2 in., 3 per cent; Brinell Hardness, 75.
Crankcases, water jackets, levers, wheel spiders.

Cu, 4; Mg. 0.6; Mn, 0.6; Quenched 510° C., 30 minutes to 6 hours, boiling water. Drawn, 150°C., 2 hours.
Wrought: Tens. Str., 60,000 lb. per sq. in.; Elongation in 2 in., 16 per cent; Brinell Hardness, 95.

Cu, 4; Mn, 0.6; Si, 0.75; Quenched, 520° C., 30 minutes to 6 hours, boiling water. Drawn, 150° C., 2 hours.
Wrought: Tens. Str., 50,000 lb. per sq. in.; Elongation in 2 in., 8 per cent (transverse).
Used for propellers, connecting rods and miscellaneous forgings.

COMPOSITIONS AND PHYSICAL PROPERTIES OF MAGNESIUM ALLOYS

Al, 4; Mn, 0.4:	Tensile Strength, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Brinell Hardness Number
Sand cast	20 000 to 26 000	2 000 to 4 000	4 to 8	4 to 8.5	53
Extruded	38 000 to 42 000	6 000 to 8 000	16 to 18	22 to 28	60
Hot rolled	30 000 to 38 000	....	16 to 18	16 to 18	56
Cold rolled	42 000 to 48 000	....	5 to 8	6 to 10	62
Cold rolled and annealed	37 000 to 42 000	....	20 to 26	22 to 28	54
Forged	31 000 to 34 000	3 000 to 6 000	5 to 18	5 to 14	60

A series of alloys under the name of Dow Metal contains aluminum with small amounts of magnesium, copper, zinc and cadmium. The German Metal Electron has a number of compositions also. The following table is given by Jeffries (1929):

		Tensile Strength, lb. per sq. in.	Elongation, per cent	Brinell Hardness Number
Dow Metal (AM-4.4): Al, 4; Mn, 0.4	Sand cast	23 000	8	48
	Chill cast	30 000	10	50
	Wrought	42 000	18	54
Dow Metal (AM-7.4): Al, 7; Mn, 0.4	Sand cast	24 000	5	51
	Sand cast and heat treated	32 000	8	51
	Wrought	44 000	13	56
	Wrought and heat treated	43 000	13	50
Dow Metal (D): Al, 8.5; Cd, 1; Cu, 2; Zn, 0.5; Mn, 0.15	Cast	22 000	2	58
Dow Metal (E): Al, 6; Mn, 0.25	Sand Cast	26 000	7	52
	Wrought	42 000	11	58
Dow Metal (T): Al, 2; Cd, 2; Cu, 4; Mn, 0.15	Sand cast	21 000	3	45
	Die cast	21 000	3	70
Electron V 1: Al, 10; Mn, 0.2-0.5	Wrought	50 000	8	70
	Wrought and heat treated	57 000	4	87
Electron AZF: Al, 4; Mn, 0.2-0.5; Zn, 3	Sand cast	26 000	5	45
	Chill cast	30 000	8	52
Electron AZM: Al, 6; Mn, 0.2-0.5; Zn, 1	Wrought, soft	43 000	14	55
	Wrought, hard	53 000	1	65
Electron AZD: Al, 5; Cd, 3; Mn, 0.2-0.5; Zn, 3	Extruded, soft	45 000	11	60
	Extruded, hard	56 000	1	70
Electron 23: Zn, 3	Extruded, soft	33 000	16	42
	Extruded hard	43 000	2	60

TIN-BASE ALLOYS

	Sn	Sb	Cu	Pb	Other Elements and Comments
Algiers Metal	94.5	0.5	5.	....	
Algiers Metal	90.	10.	....	....	
Algiers Metal	75.	25.	....	....	
Ashberry Metal	80.	14.	2.	....	Zn, 1.; Ni, 3.
Ashberry Metal	79.	15.	3.	....	Zn, 2.; Ni, 1.
Ashberry Metal, Brittania	77.8	19.4	2.8	....	
Ashberry Metal, Brittania	77.9	19.4	....	....	Zn, 2.8
Argentin	85.	14.5	0.5	....	
Aluminum Solder	85–50	....	....	....	Zn, 15–50
Bureau of Standards SN 1	78.	....	....	....	Al, 9; Zn, 8; Cd, 5
Bureau of Standards SN 2	69.	....	....	....	Al, 2.4; Zn, 26; P, 2.4
Bureau of Standards SN 3	86.	....	....	....	Al, 5; Zn, 9; P, 0.25
Bureau of Standards SN 4	86.	....	....	....	Al, 5; Zn, 9
Burgess	76.	....	....	....	Zn, 21.; Al, 3.
Frismuth	67.	....	....	27.	Al, 3.
Grimm's	69.1	....	....	28.8	Zn, 1.44; Ag, 0.72
Grimm's	50.	....	....	25.	Zn, 25.
Aluminum Solder, High Strength	56.4	....	3.	....	Zn, 37.6; Al, 3.
Aluminum Solder	67.5	....	1.	....	Zn, 16.5; Al, 15; Tens. Str., 7100 lb per sq. in.
Aluminum Solder	53.	....	....	....	Zn, 40; Al, 7; Tens. Str., 6700 lb. per sq. in.
Aluminum Solder	33.	2.	1.5	12.5	Zn, 50; Bi, 1; Tens. Str., 6000 lb. per sq. in.
Richard's	71.5	....	....	....	Zn, 25; Al, 3.5
Wegner and Guhr's	80.	....	....	....	Zn, 20.
Wilmotts	86.	....	....	....	Bi, 14.
Various	Bal.	....	....	....	Zn, 8–15; Al, 5–12.
	50.	....	....	33.3	Zn, 66.6
	47.5	....	....	47.5	Ca, 5.
	49.5	3.43	1.1	26.06	Zn, 20.31
	85.	....	....	....	Al, 10.; P Sn, 5.
Babbitt's, Original	89.	7.3	3.7	....	
Babbitt's, Hard	83.3	8.3	8.4	....	
Bearings:					
Navy Composition W	89.	7.3	3.7	....	
Navy	91.	4.5	4.5	....	
Prussian	91.	6.	3.	....	
Prussian	90.	6.	4.	....	
English	90.	7.	3.	....	
Russian Railroad	90.	8.	2.	....	
Automobile, American	89.	7.	4.	....	
Automobile, American	89.3	8.9	1.8	....	
Automobile, American	88.9	7.4	3.7	....	
Automobile, American	87.	7.	6.	....	
Heavy	85.	7.5	7.5	....	
French Car	83.3	11.1	5.5	....	
German Railroad	83.	11.	6.	....	
Valve Rods, etc	82.	10.	8.	....	
French Railroad	82.	12.	6.	....	
Piston	81.	12.5	6.5	....	
Swiss Railroad	80.	10.	10.	....	
English	76.7	15.5	7.8	....	
German	76.	17.	7.	....	
	75.	15.	....	10.	
	75.	12.	3.	10.	
	74.	9.5	4.7	11.8	
Prussian	74.	15.	11.	....	
Prussian	73.	18.	9.	....	
Prussian	72.	26.	2.	....	

TIN-BASE ALLOYS (*Continued*)

	SN	SB	CU	PB	OTHER ELEMENTS AND COMMENTS
Bearings (*Continued*):					
(Kamarsch)	71.4	7.2	21.4	....	
Valve Packing	71.	24.	5.	....	
German (Ludenscheidt)	71.8	24.3	3.85	....	
German	70.8	15.1	4.9	9.2	
(Kamarsch)	70.7	19.7	9.5	....	
G. W. R. England	67.	11.	22.	....	
French Railroad	67.	22.	11.	....	
Various	61.	10.5	2.8	25.5	
	50.	12.	1.	37.	
	42.	16.	2.	40.	
	45.	15.	....	40.	
	38.	25.	....	37.	
Bearings (Schmidt)	80.	12.	6.	2.	
Bearings (Schmidt)	70.	13.	5.	12.	
Bearings (Schmidt)	50.	14.	3.	33.	
Bearings (Schmidt)	42.	14.	3.	41.	
S. A. E. 10	91.	4.5	4.5	0.35	
S. A. E. 11	86.	6–7.5	5–6.5	0.35	
S. A. E. 12	59.5	9.5–11.5	2.25–3.75	26.	
Brittania:					
English	94.	5.	1.	....	
English	90.	6.	2.	....	Bi, 2.
English	90.	7.	3.	....	
English	85.5	9.7	1.8	....	Zn, 3.
Cast	90.6	9.2	0.2	....	
Cast	85.5	10.5	1.	....	Zn, 3.0
Cast Tutania	91.4	....	0.7	7.62	Zn, 0.25
Cast Tutania	92.35	4.65	2.45	0.32	
Birmingham I	90.57	9.38	0.03	....	
Birmingham II	85.5	10.5	1.	....	Zn, 3.0
Sheet	91.5	7.1	1.4	....	
Sheet	90.6	7.8	1.5	....	
Spinning	93.7	3.75	2.6	....	
Spoons	88.4	8.7	2.9	....	
Spoons	85.5	14.4	0.15	....	
Spoons	84.7	5.0	3.7	....	Bi, 4.9; Zn, 1.
Spoons	88.42	8.68	2.8	....	
Spoons	85.42	14.42	0.15	....	
Spoons	84.46	5.62	3.68	....	Zn, 1.53; Bi, 4.88
Plate, Hard Spelter	90.62	7.81	1.46		
Plate, Birmingham	91.46	7.12	1.4	....	
Plate, Tutania	90.	....	2.7	6.0	Zn, 1.3
Plate, Deutsch (Ludenscheidt)	71.85	24.26	3.85	....	
German	84.	9.	2.	....	Zn, 5.
German	81.9	16.3	1.8	....	
German	70.82	15.10	4.91	9.21	
German, Various, Turn	93.65	3.75	2.63	....	
German, Queen's Metal	88.52	7.10	3.48		
Blatt-Silver	91.1	....	....	0.35	Zn, 8.25; Fe, 0.23
Buckeye Bronze	41.6	....	0.6	15.6	Zn, 37.8; Al, 4.3
Bushing, Russian	72.2	....	1.3	....	Zn, 26.5
Clichier Metal	48.	10.5	....	32.5	Bi, 9
Clichier Metal	80.	....	....	5.	Bi, 15.
Deurance Metal (Locomotive)	33.3	44.5	22.2	....	
Dudley Antifriction	98.13	....	1.6	0.25	
English Pewter	81.2	5.7	1.6	1.15	
Fahlun Brilliant's	60.	....	....	40.	
Fahrig Antifriction	90.	....	10.	....	
Gilding Foil	97.6	....	2.16	....	Fe, 0.11

TIN-BASE ALLOYS (*Continued*)

	SN	SB	CU	PB	OTHER ELEMENTS AND COMMENTS
Hard Head	90.	8.	2.	....	
Hammonia Metal	64.5	....	3.25	....	Zn, 32.25
Hawk Brand White Metal	53.2	7.87	0.48	38.48	
Hoyles Metal	46.	12.	....	42.	
Hoyt's No. 11 Bearing	91.4	3.5	4.3	0.18	Ni, 0.55
Husmann Metal	73.6	11.	4.	10.6	Zn, 0.18; Fe, 0.22
Jacoby Metal	85.	10.	5.	....	
Kamarsch Bearing	85.	5.	3.6	3.4	Bi, 1.6; Zn, 1.4
Minofor (Brittania)	68.5	18.2	3.3	....	Zn, 10.
Minofor	66.	20.	4.	....	Zn, 9.; Fe, 1.
Navy Bearing	89.	7.3	3.7	....	
Navy Bearing Hard	80.	15.	5.	....	
Nico Metal	....	....	....	....	Sb, Pb, Sn, containing Ni
Parsons White Brass	60.	....	5.	....	Zn, 35.
Parsons White Brass	81.	11.	4.5	3.5	
Parsons White Brass	76.	6.	5.	13.	
Pewter	80.	....	....	20.	
Pewter	73.5	5.5	1.	20.	
Pewter	88.42	7.16	3.54	....	Zn, 0.88
Pewter	81.2	5.7	1.6	11.5	
Pewter	89.3	7.6	1.8	....	Bi, 1.8
Pewter	81.2	....	5.7	11.5	Zn, 1.6
Pewter	89.3	7.6	1.8	1.8	
Pewter	84.7	1.7	6.8	....	Bi, 6.
Phosphor Tin	95.	....	....	....	P, 5.0
Phosphor Tin	90.	....	....	....	P, 10.
Plastic Metal	80.5	8.6	9.5	....	Fe, 1.4
Poterie d'Etain	90.	9.	1.	....	
Prince's Metal	84.75	15.25	....	....	
Queen's Metal	50.5	16.5	....	16.5	Zn, 16.5
Queen's Metal	87.	8.5	3.5	....	Zn, 1.
Queen's Metal	73.36	8.88	....	8.8	Zn, 8.88
Queen's Metal	88.5	7.1	3.5	....	Zn, 0.9
Queen's Metal	88.5	7.	3.5	....	Bi, 1.0
Regel-Metal	88.3	11.1	5.5	....	
Richard's Plastic Babbitt	82.43	9.77	8.10	....	
Russian	72.2	....	1.3	....	Zn, 26.5
Silver Solder	75.	....	3.	....	Ag, 10; Zn, 2.
Ships Nail Alloy	50.	17.	....	33.	
Silver Foil	90.	....	....	....	Zn, 10.
Silver Foil	97.5	....	2.5	....	
Stanniol, or Zinn	98.9	....	0.33	0.7	
Stanniol	96.2	....	1.	2.4	Ni, 0.3; Fe, 0.1
Stereotype Metal	60.	5.	....	35.	
Tinfoil	87.5	0.5	4.	8.	
Tinman's Solder	66.5	....	....	33.3	
Tourun Leonard's Metal	90.	....	10.	....	
Trabuk Metal	87.5	5.	....	....	Ni, 5.5; Bi, 2.
Tinsel	60.4	....	....	39.6	
Tutania, Cast	91.4	....	0.7	7.62	Zn, 0.25
Tutania, Cast	92.4	4.6	2.5	0.32	Fe, 0.13
Tutania, English	80.	16.	2.7	....	Zn, 1.3
Tutania, Plate	90.	....	2.7	6.0	Zn, 1.3
Wheel Brand Babbitt	83.	14.	3.	....	
White Metal, Hanover	86.8	7.6	5.6	....	
White Metal, Dutch	81.5	8.8	9.6	....	
White Metal, Small Castings	75.	20.	....	5.	
White Metal	53.	10.6	2.4	33.	Zn, 1
White Metal	66.6	....	....	33.3	

LEAD-BASE ALLOYS

	Pb	Sn	Sb	Cu	Other Elements and Comments
Accumulator Metal (Condenser Foil)	90.	9.25	0.75	....	
Aluminum Solder, Frismuth	27.	67.	....	....	Al, 3.
Amaloy	95.6	3.6	....	0.02	
Anode Metal	94.	....	6.	....	
Anode Metal (for Zinc)	98.8	....	....	....	Ag, 1; As, 0.2
Antifriction	88.	....	12.	....	
Antifriction	84.	....	16.	....	
Antifriction	78.8	....	19.6	....	Zn, 1.; Fe, 0.6
Antifriction	77.	10.	12.5	0.5	
Antifriction	77.	8.	14.	1.	
Antifriction	60.	....	20.	....	Zn, 20.
Bahn Metal	Bal.	....	....	....	Na, 0.58; Ca, 0.73; Li, 0.05; Brinell Hardness, 34; at 100° C., 17
Battery Plates	94.	....	6.	....	
Bearing	80.5	11.6	7.4	0.5	
Bearing (Katzenstein)	75.6	7.3	16.8	0.4	
Bearing	73.0	8.5	18.0	0.4	
Bearing	68.0	9.6	20.5	1.6	
Bearing	71.8	7.7	18.5	2.	
Bearing	62.5	26.2	10.	1.3	
Bearing	61.0	25.0	13.0	1.0	
Bearing	48.	40.	10.	2.	
Bearing (American)	46.	36.5	16.5	1.0	
Bearing	86.	1.	13.	....	
Bearing	83.3	8.3	8.3	....	
Bearing	82.	2.	16.	....	
Bearing	80.	10.	10.	....	
Bearing Compagnie de l'Est	80.	12.	8.	....	
Bearing	80.	5.	15.	....	
Bearing	76.	7.	17.	....	
Bearing, American Railroad	73.5	8.	18.5	....	
Bearing, French Railroad	70.	20.	10.	....	
Bearing, Paris-Lyon-Mediterranean Railroad	70.	10.	20.	....	
Bearing, American Railroad	68.	21.	11.	....	
Bearing, Graphite Metal	68.	15.	17.	....	
Bearing	62.	27.	10.	....	
Bearing	60.	20.	20.	....	
Bearing, Chemin de fer de l'est Franc	42.	42.	16.	....	
Bearing	40.	45.	15.	....	
Bearing, Italian Railroad	37.	38.	25.	....	
Bearing, S. A. E. 13	85.	5.	10.	0.5	
Bearing, S. A. E. 14	75.	10.	15.	0.5	
Bearings (Schmidt)	64.	20.	14.	2.	
Bearings (Schmidt)	73.5	10.	15.	1.5	
Bearings (Schmidt)	78.5	5.	15.	1.5	
Bull Alloy	80.9	....	18.3	....	Fe, 0.6
Cable Sheathing	97.	3.	....	....	
Cable Sheathing	99.2	....	0.8	....	
Cable Sheathing	98.25	1.25	....	....	Cd, 0.25
Capsule Metal	92.	8.	....	....	
Clichier Metal	46.	33.	....	....	Cd, 21.
Clichier Metal	50.	36.	....	....	Cd, 14.
Clichier Metal	32.5	48.	10.5	....	Bi, 9.
Clichier Metal	5.	80.	....	....	Bi, 15.
Dippit	94.5	5.	....	0.05	
Eel Brand Antifriction	75.	6.	15.	0.9	Cd, 1.5; Ni, 1; As, 0.5; P, 0.1
Electrotype Metal	93.	3.	4.	....	
English Linotype	83.	5.	12.	....	

LEAD-BASE ALLOYS (*Continued*)

	Pb	Sn	Sb	Cu	Other Elements and Comments	
English Stereotype	82.5	4.5	13.	....		
Ferry Metal	96.75	....	....	....	Ba, 2; Ca, 1; Hg, 0.25; Brinell Hardness, aged, 24.4	
Frary Metal	98.	....	....	....	Ba Ca, 2.	
Fahlun Brilliants	40.	60.	....	....		
Foil-Lead (Calin)	86.5	12.5	....	1.0		
French Auto	75.	10.	15.	....		
Glievor Bearing	76.5	8.	14.	....	Fe, 1.5	
"Glyco"	80.5	4.5	14.5	....	As, 0.5	
Graphite Metal	68.	15.	17.	....		
Hard Lead	80.	7.5	12.	0.5		
Hoyle's Metal	42.	46.	12.	....		
Hydrone	67.	....	33.	....		
Jacana Metal	70.	10.	20.	....		
Lead Calcium	97.	....	....	....	Ca, 0.79; Ba, 0.66	
Lead Calcium (Filipoff)	Bal.	....	....	1.37	Ca, 1.9; Sr, 1.0; Ba, 1.1; Na, 0.1	
Locomotive Bushing	65.6	8.8	15.4	....		
Linotype Metal	85.	3.	12.	....		
Lurgi Metal	98.	....	....	....	Ba, 2	
Mackenzie Metal	70.	13.	17.	....		
"Magnolia"	78.	6.	16.	....		
"Magnolia"	79.75	5.	15.	....	Bi, 0.25	
Marine Babbitt	72.	21.	7.	....		
Metallic Packing	82.25	4.75	13.	....		
Metallic Packing, Compagnie d'Orleans	76.	14.	10.	....		
Monotype	74.	8.	18.	....		
Mystic Metal	88.7	....	10.8	....	Bi, 0.1.; Fe, 0.4	
Non-pareil	78.35	4.95	16.7	....		
Noheet	Bal.	....	....	....	Na, 0.5–4.	
Noheet	98.41	0.08	0.11	....	Na, 1.4	
Piston Packing, Compagnie de Nord	73.	12.	15.	....		
Regulus Metal	Bal.	....	6–8	....	Cu, less than 0.1; Sn, 0.1; As, 0.01; Zn, 0.01; S, 0.02	
Regulus Metal	Bal.	....	8–10	....		
Regulus Metal	Bal.	....	10–12	....	B.E.S. No. 335.	
Regulus Metal	Bal.	....	12+	....		
Shot Lead	99.8	....	....	....	As, 0.2	
Solder	60.	39.	1.	....		
Solder, wiping	60.	38.	2.	....		
Plumbers	66.6	33.3	....	....		
Half and Half	50.	50.	....	....		
Tinman's	33.3	66.6	....	....		
Solder, High Melting	96.	4.	....	....	P, trace	
Solder, High Melting	97.5	....	....	....	Ag, 2.5	
Solder	68.	22.	....	....	Cd, 10	
Solder, Silverstein	Bal.	....	....	0.25	Ag, 2.5	
Solder Metal A.S.T.M. (B 32 − 21)					Melting Point	Liquation Point
0 A	37.	63.	0.12	0.08	181° C.	181° C.
1 A (S. A. E. 1)	50.	50.	....	....	181° C.	213° C.
2 A (S. A. E. 2)	55.	45.	....	....	181° C.	225° C.
3 A (S. A. E. 3)	60.	40.	....	....	181° C.	237° C.
4 A	62.5	37.5	....	....	181° C.	241° C.
5 A	67.	33.	....	....	181° C.	252° C.
1 B	50.	49.25	0.75	0.15	185° C.	208° C.
2 B	55.	43.5	1.5	0.15	188° C.	220° C.
3 B	60.	38.	2.0	0.15	188° C.	228° C.
4 B	62.5	35.5	2.0	0.15	188° C.	231° C.
5 B	67.	31.	2.0	0.15	188° C.	235° C.

LEAD-BASE ALLOYS (*Continued*)

	Pb	Sn	Sb	Cu	Other Elements and Comments	Melting Point
Navy. 46S14.						
A	....	49.	0.25	0.08	Sn + Pb, 99.65	180-215° C.
B	....	44.	0.25	0.08	Sn + Pb, 99.65	180-230° C.
C	....	38.	0.25	0.08	Sn + Pb, 99.65	180-245° C.
D	....	35.	1.5	0.3	Sn + Pb, 97.5	.190-230° C.
E	....	30.	1.5	0.3	Sn + Pb, 97.5	190-240° C.
S. A. E. 4 Solder A	75.	24.5–25.5	0.12	....		
S. A. E. 4 Solder B	75.	22.5–23.5	2.0	....		
Stereotype Metal	82.	6.	12.	....		
Stereotype Metal	82.	3.2	14.8	....		
Stereotype Metal	76.	4.	20.	....		
Stereotype Metal	70.	7.	23.	....		
Stereotype Metal	67.	17.	16.	....		
Stereotype Metal	35.	60.	5.	....		
Tandem	77.7	5.9	16.8	....		
Tea Lead	98.	2.	....	....		
Terne Metal	80.25	18.	1.75	....		
Thermit Metal	72–78	5–7	14–16	0.8–1.2	Ni, 0.7–1.5; Cd, 0.7–1.5; Brinell Hardness, 29; at 100° C., 15	
Type Metal	70.	10.	18.	2.0		
English, Old	69.2	9.1	19.5	1.7		
English	63.2	12.	24.	0.8		
English	60.5	14.5	24.2	0.8		
Krupp	59.6	12.	18.	4.7	Ni, 4.7; Bi, 1.	
English	58.	15.	26.	1.		
English	77.5	6.5	16.	....		
German	75.	2.	23.	....		
German	60.	35.	5.	....		
German	60.	34.6	5.4	....		
German	60.	15.	25.	....		
Common	60.	10.	30.	....		
Common	55.5	40.	4.5	....		
French	55.	22.	23.	....		
French	55.	15.	30.	....		
Best	50.	25.	25.	....		
Ulco (see Frary)	98.5	....	....	....	Ba Ca, 1.5	
Ulco Metal	Bal.	....	....	....	Ba, up to 2; Ca, up to 1	
White	77.	5.	15.	2.3		
White	33.	53.	10.6	2.4	Zn, 1	
White	33.9	49.1	13.6	3.3		

WHITE METAL BEARING ALLOYS A.S.T.M. B 23 - 26

Alloy Grade No.	Approximate Composition, per cent					Yield Point, lb. per sq.in.		Tensile Strength, lb. per sq. in.		Brinell Hardness Number		Melting Point, deg. Cent.	Pouring Temperature, deg. Cent.
	Sn	Sb	Pb	Cu	As	20° C.	100° C.	20° C.	100° C.	20° C.	100° C.		
1 (S. A. E. 10)	91.	4.5	0.35	4.5	0.1	4400	2650	12 850	6950	17.	8.	223	441
2	89.	7.5	0.35	3.4	0.1	6100	3000	14 900	8700	24.5	12.0	241	424
3	83.3	8.3	0.35	8.3	0.1	6600	3150	17 600	9900	27.	14.5	240	491
4	75.	12.	10.	3.	0.15	5550	2150	16 150	6900	24.5	12.	184	377
5	65.	15.	18.	2.	0.15	5050	2150	15 050	6750	22.5	10.	181	366
6	20.	15.	63.5	1.5	0.15	3800	2050	14 500	8050	21.	10.5	181	346
7 (S. A. E. 14)	10.	15.	75.	0.5	0.2	3550	1600	15 650	6150	22.5	10.5	240	338
8	5.	15.	80.	0.5	0.2	3400	1750	15 600	6150	20.	9.5	237	341
9 (S. A. E. 13)	5.	10.	85.	0.5	0.2	3400	1550	14 700	5850	19.	8.5	237	327
10	2.	15.	83.	0.5	0.2	3350	1850	15 450	5750	17.5	9.	242	332
11		15.	85.	0.5	0.25	3050	1400	12 800	5100	15.	7.	244	332
12		10.	90.	0.5	0.25	2800	1250	12 900	5100	14.5	6.5	245	329

ZINC-BASE ALLOYS

	Zn	Cu	Sn	Sb	Pb	Other Elements and Comments
Aluminum Solder, Frismuth	47.5	5.5	31.5	....	....	Al, 10.5; Ag, 5.5
Aluminum Solder, Frismuth	47.4	5.3	36.8	....	....	Al, 10.5
Aluminum Solder	30.	....	65.	....	....	Bi, 5.
Aluminum Solder	50.	1.5	33.	2.	12.5	
Aluminum Solder	57.	....	....	....	....	Cd, 43.
Aluminum Solder, Mourey	94.	2.	....	....	....	Al, 4.
Aluminum Solder, Mourey	80.	8.	....	....	....	Al, 12.
Aluminum Solder, Bourbouse	81.82	....	....	....	....	Al, 18.18
Aluminum Solder, Cornande and Cruiys	52.	....	30.	....	....	Al, 17.5; Ni, 0.5
Aluminum Solder, Richards	25.	....	71.5	....	....	Al, 3.5
Battery Plates	63.4	3.2	21.3	....	12.	
Babbitt Metal	69.	5.	19.	3.	5.	
Bearing, Hard	90.	7.	1.5	1.5	....	
Bearing	88.	8.	2.	2.	....	
Bearing	85.	5.	10.	....	....	
Bearing	77.	5.5	17.5	....	....	
Bearing, English	67.7	7.4	14.9	....	....	
Bearing	66.5	4.2	29.3	....	....	
Bearing	55.	0.55	22.7	....	....	Al, 20.; Pb, 1.25
Biddery	90.2	6.3	0.8	....	2.6	
Biddery, Henie's	84.3	11.4	1.4	....	2.9	
Birmingham, Platina	79.4	20.25	....	....	....	Fe, 0.33
Brittania, Cast	48.	3.	48.	....	1.	
Button	80.	20.	....	....	....	
Cook's Alloy	31.5	....	....	68.5	....	
Cook's Alloy	43.	....	....	57.	....	
Die Casting (N. J. Zinc Co., Inc.)	92.9	3.	....	....	....	Al, 4; Mg, 0.1
Dunnlevic and Jones	52.	1.6	46.	0.4	....	
Dunnlevic and Jones Antifriction	20.	....	....	20.	60.	
Dunnlevic and Jones Antifriction	85.	5.	....	10.	....	
Dunnlevic and Jones, Russian	80.	8.	....	12.	....	
Ehrhardt's Metal	89.	4.	4.	....	3.	
Ehrhardt's Type	89.	3.	6.	....	2.	
English White Metal	76.2	5.6	17.5	....	0.7	
Fenton's Alloy	80.	6.	14.	....	....	
Fenton's Alloy	80.	8.5	....	11.5	....	
Glievor Bearing	73.5	4.4	6.7	9.	5.	Cd, 1.4
Hamilton Metal	93.4	3.5	....	1.5	3.1	Phos. Tin, 5
Heavy Axle	47.	1.	38.	6.	4.	
Hammonia Metal	32.25	3.25	64.5	....	....	
Iridium	77.25	1.12	21.63	Trace	....	
Iridium	83.00	1.25	15.75	Trace	....	
Kemler	76.	9.	....	....	....	Al, 15
Kneiss Metal	50.	....	25.	....	25.	
Kneiss Metal	40.	3.	15.	....	42.	
Leddel Alloy	90.	5.	....	....	....	Al, 5
Ledebur's Bearing	85.	5.	....	10.	....	
Ledebur's Bearing	77.	5.5	17.5	....	....	
Leddel Bearing	87.5	6.25	....	....	....	Al, 6.25
Lumen	86.	10.	....	....	....	Al, 4
Lumen	85.	10.	....	....	....	Al, 5
"Hartzink"	91.9	0.13	....	....	2.4	Fe, 5.3
Parsons White Brass	30.	5.	65.	....	....	
Pattern Metal	40.	....	40.	....	20.	
Pattern Metal	40.	....	15.	....	42.	Cu, 3
Pattern Metal	30.	....	40.	....	30.	
Pierrot Metal Beugnot	83.3	8.3	7.6	3.5	3.	
Propeller Bushing	69.	5.	19.	7.	....	
Pump Cocks	72.	7.	21.	....	....	
Richards	96.	....	....	....	....	Al, 4

ZINC-BASE ALLOYS (*Continued*)

	Zn	Cu	Sn	Sb	Pb	Other Elements and Comments
Russian, Packing	98.5	....	0.98	....	0.32	Fe, 0.16
Russian	26.5	1.3	72.2	....	....	
Salge Metal	85.5	4.	9.9	....	1.1	
Schomberg Alloy	87.	3.	10.	....	....	
Schomberg-Bearing	59.4	0.38	39.8	....	0.21	Fe, 0.15
Schulz	91.	6.	....	....	....	Al, 3
Silver Leaf	8.25	....	91.	....	0.35	
Silver Metal	66.5	....	....	....	....	Ag, 33.5
Siemens Halske	48.	....	....	5.	....	Cd, 47
Siemens Halske, Automobile	47.5	....	....	5.	....	Cd, 47.5
Sorel's Alloy	98.	1.	....	....	....	Fe, 1
Sorel's Alloy	80.	10.	....	....	....	Fe, 10
Spandau	Bal.	4–6	....	....	....	Al, 2–3.5
Spiauter (Hard Zinc)	90.	2.	....	8.	....	
Tenax	Bal.	2.56	....	....	0–1.2	Al, 4.4; Fe, 0–0.35
Vaucher's Alloy	75.	....	18.	2.5	4.5	
War Bronze	Bal.	4.85	0.15	....	0.92	Al, 2.2
Zamac	Bal.	....	....	....	....	Small amount of Cu and Al
Zamak (Die Cast)	Bal.	2.5–3.5	....	....	....	Al, 3.5–4.5; Mg, 0.2 max.
Zelco	83.	2.	....	....	....	Al, 15.0
Zilloy, Cold Rolled	Bal.	1.	....	....	....	Cd, 0.8; Mg, 0.01

FUSIBLE METALS

	Bi	Sn	Pb	Cd	Other Elements and Comments	Temperature of Fusion
Anatomical Alloy	53.5	19.	17.	....	Hg. 10.5	60° C.
Bismuth Solder	40.	20.	40.	....		
Bismuth Solder	33.3	33.3	33.3	....		
Bismuth Solder	27.5	45.	27.5	....		
Bismuth Solder	25.	50.	25.	....		
Clichier Metal	15.	80.	5.	....		
	9.	48.	32.5	....	Sb, 10.5	
	....	36.	50.	14.		
	....	33.	46.	21.		
D'Arcet	50.	25.	25.	....		
Eutectic	49.5	13.1	27.3	10.1		70–74° C.
Eutectic Bi, Pb, Cd	51.6	....	40.2	8.1		91.5° C.
Eutectic Bi, Sn, Pb	52.5	15.5	32.	....		96° C.
Eutectic Bi, Sn, Cd	54.	26.	....	20.		103° C.
Eutectic Bi Pb	56.5	....	43.5	....		125° C.
Eutectic Bi, Sn	58.	42.	....	....		137° C.
Eutectic Bi, Cd	61.5	....	....	38.5		144° C.
Eutectic Sn, Pb, Cd	....	50.	32.	18.		145° C.
Eutectic Sn, Cd, Zn	....	73.5	....	24.5	Zn, 2	163° C.
Eutectic Sn, Cd	....	68.5	....	31.5		178° C.
Eutectic Sn, Pb	....	63.	37.	....		182° C.
Eutectic Sn, Zn	....	91.5	....	....	Zn, 8.5	197° C.
Eutectic Pb, Sb	....	....	87.	....	Sb, 13	247° C.
Eutectic Pb, Cd	....	....	77.	23.		249° C.
Fusible Tea Spoons	44.5	16.5	30.	....	Hg, 5–10	
Guthrie's	47.38	19.97	19.36	13.29		
Lictenberg	50.	20.	30.	....		
Lipowitz	50.	13.3	26.7	10.		
Newton's	50.	18.75	31.25	....		
Onion's	50.	20.	20.	....		
Rose's	50.	22.	28.	....		
Rose's	35.	30.	35.	....		
Wood's	50.	12.5	25.	12.5		

GOLD ALLOYS

	AU	AG	CU	OTHER ELEMENTS AND COMMENTS
Standard Gold, British	91.66	....	8.33	
Standard Gold, U. S	90.	....	10.	
Coinage Alloys:				
Edward III Old Sterling	99.48	....	Bal.	
Ducat, Austria	98.6	....	Bal.	
Double Ducat, Holland	98.3	....	Bal.	
£1, Egypt	87.5	7.5	5.	
50 piastre, Egypt	87.5	2.5	10.	
Siam	65.	....	Bal.	
22 Carat	91.66	4.166	4.166	
22 Carat Dental, Dark	91.57	4.99	3.44	
22 Carat Dental, Light	91.57	8.43	....	
20 Carat	83.33	8.33	8.33	
20 Carat	83.20	10.81	5.99	
18 Carat	75.0	10.4	14.6	
18 Carat	75.00	12.00	13.00	
18 Carat	75.00	14.6	10.4	
18 Carat Dental	74.88	19.13	5.99	
18 Carat Special	75.00	20.00	5.00	
16 Carat	66.6	6.6	26.6	
16 Carat	66.66	11.12	22.22	
16 Carat	66.6	19.4	13.8	
16 Carat	66.45	25.57	7.98	
15 Carat	62.49	11.01	13.25	
14 Carat	58.3	4.16	37.5	
14 Carat Regular	58.33	13.33	28.34	
14 Carat Spring	58.33	16.00	25.67	
14 Carat	58.3	25.	16.6	
14 Carat Special	58.33	27.77	13.90	
14 Carat Dental	58.03	30.03	11.94	
12 Carat	50.00	14.58	35.42	
10 Carat Regular	41.66	12.34	46.00	
10 Carat	41.6	16.6	41.6	
10 Carat Spring	41.66	20.00	38.34	
8 Carat	33.30	20.00	46.70	
Pale Yellow Gold	91.6	8.3	....	
Pale Yellow Gold	91.6	....	....	Fe, 8.3
White Gold	90.	....	....	Pt, 10
Palladium Gold	90–80	....	....	Pd, 10–20
Grey Gold	85.7	8.6	....	Fe, 5.7
Grey Gold	83.3	....	....	Fe, 16.6
White Gold	75–85	....	....	Ni, 10–18; Zn, 2–9
Red Gold	75.	....	25.	
Green Gold	75.	25.	....	
Green Gold	75.	16.6	....	Cd, 8.3
Green Gold	75.	12.5	....	Cd, 12.5
Blue Gold	75.	....	....	Fe, 25.
Green Gold	74.6	11.4	9.7	Cd, 4.3
Yellow Gold	53.	25.	22.	
Dark Red Gold	50.	....	50.	
White Gold:				
Belais	75–85	....	....	Ni, 8–18; Zn, 4–14; less Zn than Ni
Belais	75–85	....	....	Ni, 10–18; Zn, 2–9; Pt, 0.05–0.5; or Mn, 0.5–2
Carter	83.3	....	....	Ni, 16.7
Dufour	75.	....	....	Pd, 21.5; Pt, 4.5
Koch	75. (min)	....	....	Ni, 3.3–24.75; Mn, 0.25–5
Liebknecht	80.	....	....	Ni, 13.9; Zn, 5; Cu, 1; Pd, 0.1
Mourey	50.	35.	....	Pd, 15
Pechko	60.	....	....	Pd, 30; Pt, 10; Ir, 0.1–2.0
Shiga	90–60	....	....	Ni, 5–20; Cr, 5–20

GOLD ALLOYS (*Continued*)

		Au	Ag	Cu	Other Elements and Comments	Melting Point	Flow Point
White Gold:							
18 Carat		75.	18.5	1.	Zn, 5.5		
14 Carat		59.	....	25.5	Ni, 12.3; Zn, 3.2		
14 Carat		58.3	....	17.	Ni, 17; Zn, 7.6		
10 Carat		41.6	....	25.	Ni, 25; Zn, 8.3		
White Gold Solder:							
18 Carat		82.	....	....	Ni, 10; Zn, 6; Cd, 2		
18 Carat		61.	13.5	1.5	Ni, 7; Zn, 17		
18 Carat		60.8	14.	4.	Ni, 6; Zn, 5.2		
14 Carat		50.	36.	1.	Zn, 11; Cd, 2		
10 Carat		30.	55.	1.	Zn, 12; Cd, 2		
Gold Solders:							
18 Carat		75.	13.	12.			
18 Carat		75.	16.6	8.3			
16 Carat		62.5	31.25	6.25			
14 Carat		50.	33.3	16.6			
12 Carat		47.8	29.	17.1	Brass, 6.1		
10 Carat		41.2	37.	21.2	Brass, 0.6		
9 Carat		25.	50.	25.			
8 Carat		40.	36.6	23.4			
Best		62.5	22.5	15.			
Easy Melt		54.5	31.75	13.75			
Very Easy Melt		11.5	54.5	28.5	Zn, 5–5		
Gold Solders, Handy & Harmon:							
18 Carat White	19 Carat Extra Hard	80.	....	....	Ni, 12; Zn, 8	845° C.	885° C
	16 Carat Hard	66.6	10.	6.4	Ni, 5; Zn, 12	750° C.	805° C.
	14 Carat Easy	58.3	15.	5.7	Ni, 6; Zn, 15	700° C.	735 C.
18 Carat Green	14 Carat Easy	58.3	18.	12.	Zn, 11.7	725° C.	740° C.
18 Carat Yellow	16 Carat Hard	66.6	15.	15.	Zn, 3.4	795° C.	815° C.
	14 Carat Easy	58.3	18.	12.	Zn, 11.7	725° C.	740° C.
14 Carat White	12 Carat Hard	50.	25.	10.	Ni, 6; Zn, 9	750° C.	795° C.
	10 Carat Easy	41.7	30.	8.3	Ni, 5; Zn, 15	695° C.	720° C.
14 Carat Green	10 Carat Easy	41.7	32.	16.3	Zn, 10	720° C.	735° C.
14 Carat Yellow	12 Carat Hard	50.	25.	22.	Zn, 3	765° C.	785° C.
	10 Carat Easy	41.7	32.	16.3	Zn, 10	720° C.	735° C.
10 Carat White	8 Carat Hard	33.3	42.	10.	Ni, 5; Zn, 9.7	710° C.	775° C.
10 Carat Green	8 Carat Hard	33.3	20.	30.	Zn, 16.7	760° C.	805° C.
10 Carat Yellow	8 Carat Hard	33.3	31.1	28.	Zn, 7.7	730° C.	780° C.
	6 Carat Easy	24.7	45.	20.	Zn, 10.3	700° C.	720° C.
Standard Golds:							
18 Carat Red		75.	5.	20.			
18 Carat Yellow		75.	15.	10.			
18 Carat Green		75.	22.5	2.5			
18 Carat White		75.	....	2.5	Ni, 17.5; Zn, 5		
14 Carat Red		58.3	2.1	39.6			
14 Carat Yellow		58.3	8.3	29.2	Zn, 4.2		
14 Carat Green		58.3	37.5	4.2			
14 Carat White		58.3	....	16.7	Ni, 16.7; Zn, 8.3		
10 Carat Red		41.7	2.9	55.4			
10 Carat Yellow		41.7	11.7	40.8	Zn, 5.8		
10 Carat Green		41.7	5.8	35.	Zn, 17.5		
10 Carat White		41.7	....	23.3	Ni, 23.3; Zn, 11.7		
Solder, Sheffield		60.	....	15.	Zn, 16; Ni, 7		
Contacts:							
Kraft and Harris		67.5–70	25.	....	Pt, 5–7.5		
Fahrenwald		45.	45.	....	Pd, 10		
Muller		90.	....	....	Ni, 10		
Gardner		75.	....	2.96	Ni, 16.7; Zn, 5.34		

GOLD ALLOYS (*Continued*)

	Au	Ag	Cu	Other Elements and Comments
Dental:				
Cooper	40–50	....	....	Pd, 50–60
Sandeel	80.	....	....	W, 10.; Ni, 7
Stovall	72.	....	16.5	Ni, 13.5; Pt, 2
Van Allen	64.	18.75	9.	Pd, 8.; Al, 0.25
Whiteley	45–55	....	....	Pd, 30–35.; Pt, 15–20
Davignon	58.	....	37.	Al, 5
Electrical	70.	25.	....	Ni, 5
Fuchs Acid Resisting	75.	....	....	Ni, 10–15; W, 10–15
Fuchs Acid Resisting	13.5–15	73–80	....	Ni, 13.5–15
Fahrenwald Resisting	90–60	....	....	Pd, 10–40
High Strength (Wise) 14 Carat	58.35	....	16.	Ni, 17; Zn, 8.65; Tens. Str., 110,000 lb. per sq. in.; Brinell Hardness, 200–360
High Strength (Wise) 18 Carat	Bal.	....	3.5	Ni, 16.5; Zn, 5; Tens. Str., 100,800 lb. per sq. in.
Pens and Pin Tongue	58.3	16.7	22.9	Zn, 2.1
Pens, Ogawa & Kamıya	60.	....	....	W, 20; Ni, 10; Ir, 10
Pen Metal, Copper	25.	25.	50.	
Platinum Substitutes:				
Palau	80.	....	....	Pd, 20
Electrical	70.	25.	....	Ni, 5 or Pt, 5
Palladium Gold	31.	19.	39.65	Pd, 10.35
Roberts-Austen's Purple Gold	78.5	....	....	Al, 21.5
Japanese Alloys (Roberts-Austen):				
Shaku-do I	3.73	1.55	94.5	
II	4.16	0.1	95.8	
Shibu-ichi	Trace	32.1	67.3	Fe, 0.5
	0.12	48.9	51.1	
Kiu-Shibu-ichi	One part of Shaku-do, two parts of Shibu-ichi.			
Kuromi	Copper containing Sn, Co, etc.			

SILVER ALLOYS

	Ag	Cu	Zn	Sn	Other Elements and Comments
Sterling Silver	92.5	7.5	....	....	
Rupee	91.6	8.3	....	....	
Standard	90.	10.	....	....	
Coinage Alloys:					
Florin, Holland	94.5	Bal.	....	....	
Mexico, Old Peso	90.27	Bal.	....	....	
China, 1915	89.	Bal.	....	....	
Austria, Italy, France	83.5	Bal.	....	....	
Denmark, Crown	80.	Bal.	....	....	
Irish, Poland, Danzig	75.	Bal.	....	....	
Chili, Japan, Mexcio, etc	72.	Bal.	....	....	
Austria, Schilling	64.	Bal.	....	....	
Straits $1, Sweden	60.	Bal.	....	....	
Germany, Russia	50.	Bal.	....	....	
Great Britain, A	50.	50.	....	....	
Great Britain, B	50.	40.	....	....	Ni, 10
Great Britain, C	50.	45.	....	....	Mn, 5
Great Britain, 1929	50.	40.	5.	....	Ni, 5
Straits, 10 cents	40.	Bal.	....	....	
Silver Solders:					
Hard	80.	13.2	6.8	....	
Sterling	80.	2.5	17.5	....	
Medium	75.	20.	5.	....	
Medium	70.	22.5	7.5	....	
Enamel	66.7	33.3	....	....	

SILVER ALLOYS (*Continued*)

	Ag	Cu	Zn	Sn	Other Elements and Comments			
Silver Solders (*Continued*)								
Pure Silver	72.	28.	....	....				
French	66.	23.3	10.	....				
Plate	64.5	22.5	13.	....				
Common	62.5	30.	7.5	....				
Chain	62.5	31.2	6.2	....				
Chain	63.5	20.9	16.6	....				
Quick	62.5	20.9	10.4	6.2				
Quick	56.9	27.7	11.5	3.8				
Bureau of Standards	40.	14.	6.	40.	**Melting Point, 400° C.**			
A.S.T.M. (B 73 – 29):						Melting Point	Flow Point	Color
Grade No. 8	80.	16.	4.	....		740° C.	795° C.	White.
Grade No. 7	70.	20.	10.	....		725° C.	755° C.	White.
Grade No. 6	65.	20.	15.	....		695° C.	720° C.	White.
Grade No. 5	50.	34.	16.	....		695° C.	775° C.	Nearly White.
Grade No. 4	45.	30.	25.	....		675° C.	745° C.	Nearly White.
Grade No. 3	20.	45.	30.	....	Cd,5.	775° C.	815° C.	Yellow.
Grade No. 2	20.	45.	35.	....		775° C.	815° C.	Yellow.
Grade No. 1	10.	52.	38.	....		820° C.	870° C.	Yellow.
Handy and Harmon:								
Hard	75.	22.	3.	....		740° C.	785° C.	
Hard No. 1	75.	20.	5.	....		735° C.	775° C.	
RT	60.	25.	15.	....		680° C.	720° C.	
ET	50.	28.	22.	....		675° C.	725° C.	
DT	40.	36.	24.	....		720° C.	785° C.	
SS	40.	30.	28.	....	Ni, 2	670° C.	780° C.	
NT	30.	38.	32.	....		745° C.	785° C.	
NE	25.	52.5	22.5	....		815° C.	855° C.	
TL	9.	55.	38.	....		820° C.	870° C.	
Navy (47S 13a):								
II	64–70	18–23	Bal.	0.5 max.				
I	44–50	35–45	Bal.	0.5 max.				
O	22–25	45–50	Bal.	0.5 max.				
Solders, German	20.	30.	30.	....	Cd, 20			
Solders, German	10.	40.	40.	....	Cd, 10			
Solders, German	10.	3.	2.	75.				
Argent Francais (Roulz)	40.	35.	....	....	Ni, 25.			
Argent Francais (Odessa)	33.25	42.5	15.75	....	Ni, 8.5			
Argent Francais (Roulz)	33.	40.	....	....	Ni, 27.			
Argent Francais, Mousset's Silver	27.5	59.5	9.5	....	Ni, 3.5			
Argent Francais (Roulz)	20.	50.	....	....	Ni, 30.			
Silanca	92.5-94.5	....	0–2.5	....	Sb, 4–4.5; Cd, 1–3			
Fuchs Acid Resisting	73–80	....	....	....	Ni, 13–15; Au, 13.5–15			
Weiger, Contact	77–80	18–20	....	....	Pt, 2–5			
W. E., Contact	15.	81–83	....	....	Sn, 2–4			
Hyman (like Platinum)	58.3	16.7	16.7	....	Ni, 8.3			

PLATINUM, ETC.

	Pt	Au	Ag	Other Elements and Comments
Thermo-couples	90–97	....	....	Ir, 10–3
Thermo-couples	90.	....	....	Rh, 10
Carter, Contacts	Bal.	5–15	0.5–5	Pd, 0.5–5
Meyl, Contacts	....	....	Bal.	Pd, 40–80
Watch Wheels	62–75	....	....	Ni, 18; Cu, 18; Cd, 1.25
Watch Alloy	....	....	....	Pd, 70; Cu, 25; Ag, 4; Ni, 1

PLATINUM, ETC. (*Continued*)

	Pt	Au	Ag	Other Elements and Comments
Platinum-Gold:				
White	40.	60.	....	
Almost White	30.	70.	....	
Almost White	58.3	16.6	25.	
Cooper's Gold	18.75	....	....	Cu, 81.25
Cooper's Gold	29.17	....	....	Cu, 66.6; Zn, 4.15
Cooper's Pen Metal	50.	....	37.5	Cu, 12.5
Cooper's Pen Metal	....	25.	25.	Cu, 50.
Cooper's Mirror	9.5	....	....	Cu, 58,; Sn, 27,5; Zn, 3.5; As, 1.5
Resistance	33.3	....	66.6	
Solder	27.	....	73.	
Platine-au-titre	17–35	....	83–65	
Platinum Substitutes:				
Palau	....	80.	....	Pd, 20.
	20.	....	....	Ni, 60.; Pd, 10.; V, 10
Cooper's	25.	....	70.	Ni, 5.
Cooper's	....	....	70.	Co, 5.; Pd, 25.
Electrical	7.5	67.5	25.	
Electrical	5.	70.	25.	
Electrical	....	70.	25.	Ni, 5.
Palladium Gold	....	31.	19.	Pd, 10.35; Cu, 39.65
Pen Points	5.	....	....	Os, 85; Rh, 10
Pen Points	....	....	....	Ni, 60–61; Ru, 39–40

RESISTANCE ALLOYS

	Ni	Cr	Fe	Mn	Cu	Zn	Other Elements and Comments
Advance	44.3	....	0.5	1.15	53.9	....	
Alumel	94.	....	0.5	2.5	....	....	Al, 2; Si, 1
Argentan	26.	....	....	....	56.	18.	
Calido	64.	8.	25.	3.	....	....	
Calido	65.	11.	24.	....	....	....	
Calido Elalco	60.	16.	24.	....	....	....	
Calorite	65.	12.	15.	8.	....	....	
Calorite	65.	12.	23.	....	....	....	
Chromel A	80.	20.	....	....	....	....	(Up to 1100° C.)
Chromel B	85.	15.	....	....	....	....	
Chromel C	64.	11.	25.	....	....	....	
Chromel:							
502	25.	20.	55.	....	....	....	
D	26.	8.	66.	....	....	....	
P	90.	10.	....	....	....	....	
Chronin	83.7	14.7	....	....	....	....	
Cimet	25.	....	75.	....	....	....	
Climax	24.4	....	73.	2.6	....	....	
Comet	30.4	2.2	66.9	0.8	0.4	....	
Constantin	46.	....	....	....	54.	....	
Constantin	43.9	....	0.4	1.34	54.15	....	
Copel	45.	....	....	....	55.	....	
Copernick	50.	....	....	....	50.	....	
Corronil	70.	....	....	4.	26.	....	
Cronit	60.	40.	....	....	....	....	
Dilver	(See Platinite)						
Dumet	46.	....	54.	....	....	....	
Elinvar	36.	12.	Bal.	....	....	....	Used for hairsprings.
Eureka	(See Manganin)						
Excello	85.	14.	0.5	0.5	....	....	
Excelsior	45.	....	0.3	....	53.	....	
Fermet	18.	4.	Bal.	2.2	0.3	....	W, 0.5–1.0; C, 0.35

RESISTANCE ALLOYS (*Continued*)

	Ni	Cr	Fe	Mn	Cu	Zn	Other Elements and Comments
Ferrozoid	Nickel steel						
Glowray	65.	12.	23.	....	....	....	
Heating Units	60–65	12–15	Bal.	....	....	....	Up to 850° C.
Hipernick	50.	....	50.	....	....	....	
Hopkinson Alloy	24.5	....	75.	....	....	....	
Ia-Ia	40.	....	....	....	60.	....	
Ideal	45.	....	0.66	0.45	53.4	....	Al, 0.66
Ideal	40.	....	1.	1.	58.	....	
Invar	36.	....	64.	....	....	....	Coefficient of Expansion
Invariant	47.	....	Bal.	....	....	....	
Karma	80.	20.	....	....	....	....	
Kromax	80.	20.	....	....	....	....	
Kromore	85.	15.	....	....	....	....	
Kruppin	28 per cent Nickel Steel						
Lucerno	67.9	....	2.4	2.2	27.5	....	
Lucerno	65.	....	....	5.	30.	....	
Magno	95.	....	....	5.	....	....	
Magno Nickel	Bal.	....	....	2.6	....	....	
Manganese Steel	....	....	Bal.	12.	....	....	C, 1.2
Manganin	4.	....	....	12.	84.	....	
Manganin	2.	....	....	12.	86.	....	
Manganin	12.	....	....	4.	84.	....	
Manganin	2.3	....	0.6	15.	82.1	....	
Manganin	5.	....	....	25.	70.	....	
Marsh's Patent	75.	25.	....	....	....	....	
Mond No. 70	70.	....	....	4.	26.	....	
Monel	67.1	....	2.1	1.7	28.4	....	
MMM (Monel)	60–65	....	....	....	27–24	....	Sn, 9–11; Si, Fe, Mn, 1–3
Mumetal	Bal.	....	20–25	1.	5.	....	
Ni-Al Alloy	94.	....	....	....	....	....	Al, 6
Nicaloy	49.	....	51.	....	....	....	
Nickel-Chromium:							
A	78.	20.	....	1–1.5	....	....	Si, 0.5
C	65.	15.	Bal.	1–2	....	....	Si, 0.5
D	32.	6–7	Bal.	1–2	....	....	Si, 0.5
Ni-Cr-Cu	80.	25.	....	....	20.	....	Parts.
Ni-Cr-Cu	85.	20.	....	....	15.	....	Parts.
Ni-Cr-Al	88.	8.	....	....	....	....	Al, 4.
Nickelin	18.	....	....	....	62.	20.	
Nickelin	32.	....	....	....	68.	....	
Nickelin	31.5	....	....	....	55.3	13.1	
Nichroloy	75.	16.	8.	3.	....	....	
Nichroloy	40.	7.	50.	3.	....	....	
Nichroloy, cast	23.	20.	50.	1.	....	....	+ Al, Si, V, C
Nichrome I	60.	11.	25.	4.	....	....	
Nichrome II	75.	11.	12.	2.	....	....	
Nichrome	66.	22.	10.	2.	....	....	
Nichrome:							
III	85.	15.	....	....	....	....	
IV	80.	20.	....	....	....	....	
Ribbon	75.	11.	12.	2.	....	....	
Cast	67–65	20–22	12–14	1.5–2	....	....	
II	63.	10.	25.	....	....	....	Si, etc., 2
I	60.	15.	25.	....	....	....	
Non-Magnetic High Resistance	30.	70.	....	....	....	....	
Peerless	Bal.	16.5	3.	2.	....	....	
Permalloy	78.5	....	21.5	....	....	....	Magnetic Properties
Permaloy	78.	....	22.	....	....	....	
Perminvar	45.	....	30.	....	....	....	Co, 25.

RESISTANCE ALLOYS (*Continued*)

	NI	CR	FE	MN	CU	ZN	OTHER ELEMENTS AND COMMENTS
Phenix	25.	....	75.	....	....	....	
Placet	60.	15.	20.	5.	....	....	
Platinite	46–42	....	54–58	....	....	....	Coefficient of Expansion
Platinoid	24.77	....	0.47	0.15	54.	20.4	
Platinoid	15.	....	....	....	62.	22.	
Platinoid	14.	....	....	....	60.	24.	W, 1–2
Premier	Bal.	11.	25.	3.	....	....	
Rayo	85.	15.	....	....	....	....	
Redray	85.	15.	....	....	....	....	
Resistin	....	....	1.8	11.7	86.5	....	
Resistin	....	....	3.	12.	85.	....	
Rheotan	....	....	12.	....	84.	4.	
Rheotan II	25.	....	5.	....	52.5	18.	
Shemtschushny	....	....	4.45	13.8	84.2	....	Si, 0.5 Used for Manganin.
Shemtschushny	....	....	1.3	11.1	86.8	....	Si, 0.6
Silver Bronze	....	....	....	18.	67.5	13.	Al, 1.25; Si, 0.25
Stitching Wire	74.5	18.	....	7.5	....	....	
Superior	Bal.	19.5	0.5	2.	....	....	
Tarnac	(See Manganin)						
Tico	27.5	....	Bal.	....	....	....	
Tico	30.4	....	67.3	1.12	1.1	....	
Tophet	61.	10.	26.	3.	....	....	
Vestalin	(28 per cent Nickel Steel)						

HEAT-RESISTING ALLOYS

	NI	CR	FE	SI	OTHER ELEMENTS AND COMMENTS
Armstrong, Patent	.....	3–50	Bal.	0.5–8	Cr + Si, 5–58
Armstrong, Patent	.....	21.6	Bal.	3.4	Mn, 1.25; C, 2.35
Armstrong, Patent	.....	12.	Bal.	5.	C, 0.45
Atha 2600	22.	8.	Bal.	1.75	Cu, 1
Baros	90.	10.	.....	.....	
Calido	64.	8.	25.	.....	Mn, 3
Calite	35.	5.	50.	.....	Al, 10
Calite	40.	5.5	Bal.	.....	Al, 4.1
Calite A	35.	15.	Bal.	.....	C, 0.8
Calite B	6.	18.	Bal.	.....	C, 1.5
Calorite	65.	12.	15.	.....	Mn, 8
Carburizing Boxes	30–50	16–22	Bal.	.....	
Christite	.....	10.	66.	.....	W, 17; Mo, 2.5; C, 3.5
Chromax	35.	15.	Bal.	.....	
Chronite	67.	16.	12.	.....	Burners and Valves.
Chronite	63.5	13.7	20.3	0.4	Mn, 1; Al, 0.8
Clebrium	2.	13.1	Bal.	1.5	Mo, 3.6; Mn, 0.75; C, 2.6
Clebrium	4.6	18.3	Bal.	.....	Mn, 2.8; Cu, 2; C, 2
Crocar	.....	12.	Bal.	.....	Co, 0.75; V, 0.75; C, 2.15
Cyclops 17	20.	8.	Bal.	1.	C, 0.4; Mn, 0.75
Defiheat	.....	25–30	Bal.	.....	Mn, 0.5 max., C, 0.25
Duraloy, 18–8	9.	18.	Bal.	.....	Mn, 0.5
Durimet	.....	.....	.....	.....	
Elkonite (Electrode)	.....	.....	.....	.....	W, 74.25; Cu, 25.1
Enduro, K A 2	7–10	16.5–19.5	Bal.	0.75	Mn, 0.5; C, 0.15 max.
Firearmor	60.	20.	10.	.....	Mn, 1.75; C, 0.5
Firearmor	61.	18.5	20.5	.....	
Flame-resisting	9.7	14.	Bal.	0.2	Mn, 0.77; C, 0.23
Hardite	45.	15.	13.	10.6	Cu, 4; Zr, 3.45; Mn, 2; Al, 0.95
Hardite A	65.	14–16	Bal.	1–4	Mn, 1–2
Hardite B	35.	16–18	Bal.	1–4	Mn, 1–2
Hardite C	93.	.....	.....	5.	Mn, 2

HEAT-RESISTING ALLOYS (*Continued*)

	NI	CR	FE	SI	OTHER ELEMENTS AND COMMENTS
Hardite S	65.	.....	Bal.	5–7	Mn, 2
Hardite X	82–86	10–13	.....	2–4	Mn, 2
Hardite Z	6–12	15–25	Bal.	0.4	Mn, 1–3
Johnson	20–30	25–30	Bal.	1–3.5	
Johnson	9–25	10–20	Bal.	1–10	
Johnson	12–36	6–18	50.	1–10	
Krupp, K A 2	7–10	16–20	Bal.	0.75	Mn, 0.5 max.; C, 0.15
Monel Metal	(For compositions, see Copper-Nickel Alloys)				
Ni-Cr-Si Alloy	Bal.	25–30	.....	16–18	
Nichrome, Castings	60.	15.	25.	.....	C, 0.7
Nichrome	80.	13.5	4.8	1.3	
Nichrome	70.	20.	6.9	0.5	Mn, 1.9
Nichrome	70.3	13.2	7.25	3.7	Cu, 3.25; Mn, 0.2; Mo, 1.33
Nichrome	62.	13.	20.	.....	Mn, 5
Nichrome	64.7	13.3	6.4	3.36	Cu, 11; Mn, 0.6; C, 0.35
Nichrome	53.7	16.7	22.4	1.	Mn, 1.4
Non-Scaling	30–40	15–20	Bal.	3.5	Cu, 1.25
Non-Scaling	24.	24.	Bal.	3.	
Placet	60.	15.	20.	....	Mn, 5
Platnam	.....	.....	.....	.....	Cu, Ni, Steam Valves up to 600° C.
Pyra Steel	25.	15.	57.	.....	C, 0.3
Pyros	82.	7.	3.	.....	W, 5; Mn, 3
Q-Alloy, K-1	66–68	19–20	.....	.....	Bal. Si, Mn, C
Q-Alloy, X-ite	37–39	17–19	.....	.....	Bal. Si, Mn, C
Rezistals	(For compositions, see Stainless and Corrosion-Resisting Alloys)				
Rohn, non-scaling	50.	30.	17.	.....	
Silchrome	.....	9.5	Bal.	4.	C, 0.5
Spark Plugs	Bal.	.....	.....	....	Mn, 2.5–4
Spark Plugs	30.	.....	Bal.	.....	Mn, 1; C, 0.3
Spark Plugs, Radio, etc	93–97	.....	.....	2–4	Mn, 1–3
Spark Plugs, Radio, etc	82–86	10–12	.....	2–4	Mn, 1–3
Uniloy, 2	12.	21.	Bal.	.....	C, 0.2; up to 1800° F.
Uniloy, 2825	0.5	28.	Bal.	.....	C, 0.25; up to 2000° F.
Valve Seats	35.	1–5	5.	.....	Cu, Bal.
Valve Seats	60.	.....	1.5	.....	Cu, 26; Sn, 11
Valve Seats	67.	.....	2.	.....	Cu, 28; Mn, 2; C, 1

CORROSION-RESISTING ALLOYS (COPPER, ETC.)

	CU	NI	FE	OTHER ELEMENTS AND COMMENTS
Acid Metal	88.	.....	.....	Sn, 10; Pb, 2
Ajax	5–20	25–50	Bal.	
Apolloy	.....	.....	.....	Copper Sheet Steel.
Aluminum Bronze	Bal.	.....	1–4	Al, 7–10
Ambrac A	74.5	20.	.....	Zn, 5; Mn, 0.5
Ambrac B	64.5	30.	.....	Zn, 5; Mn, 0.5
Ampco Metal	80–90	.....	6–7	Al, 8–10
Barberite	88.5	5.	.....	Sn, 5; Si, 1.5
Copperoid	.....	.....	.....	Copper Bearing Steel.
Cop-r-loy	.....	.....	.....	Copper Bearing Steel.
Cufenium	72.	22.	6.	
Cufenium	60.	20.5	Bal.	
Cuniloy	25.	65.	.....	Mn, 3.8; Pb, 1
Davis Metal	67.	29.	2.	Mn, 1.5; C and Si, 0.5
Duke's Metal	30.	40.	30.	
Everbrite	60–55	30–35	Bal.	
Everbrite	55.	33.	1.5	Cr, 5; Mn, 1.5
Everdur	94.5	.....	.....	Si, 4.5; Mn, 1
Hastelloy D	3.	85.	.....	Si, 10; Al, 1.5–2

CORROSION-RESISTING ALLOYS (COPPER, ETC.) (*Continued*)

	CU	NI	FE	OTHER ELEMENTS AND COMMENTS
Hytensyl Bronze	60.	.....	6.	Zn, 19; Al, 10; Mn, 5
Lemarquand	39.	7.	.....	Zn, 37; Sn, 9; Co, 8
Marlies, Non-oxidizable	17.	35.	10.	Zn, 18; Sn, 10
Marlies, Non-oxidizable	.....	35.	10.	Zn, 10; Sn, 20; Brass, 25
Monel	.....	.....	.....	
Mond Seventy	26.	70.	.....	Mn, 4
Pioneer	25.	35.	Bal.	Mo, 0–5
Rauchberg (Sulfite)	66–75	.....	.....	Pb, 15–19; Sn, 10–5; Sb, 1–5
Seventy-Thirty	70.	30.	.....	
SML, Mond	28.	68.	2.5	Mn, 1.5
Toncan	.....	.....	.....	Copper Bearing Steel (Mo).

STAINLESS AND CORROSION-RESISTING ALLOYS

	CR	NI	FE	OTHER ELEMENTS AND COMMENTS
Abros	10.	88.	.....	Mn, 2
Acid Resisting (Nitric)	21.	30.	40.8	W, 6.2; Mn, 1.55; Si, 0.45
Acid Resisting (Nitric)	14.5	20.	56.	Co, 5; Cu, 4.5
Acid Resisting (Nitric)	15.	53.	23.	W, 4; Si, 3.75; Mn, 1.25
Acme Ni Steel	14.2	30.3	Bal.	C, 0.3
Alleghany Metal	17–20	7–10	Bal.	Max., Mn, 0.5; Si, 0.5; C, 0.2
Appolo Crom	.....	.....	.....	Chromium plated Zinc sheet.
Armstrong	12.	.....	Bal.	Si, 5; C, 0.45
A R C	12.	35.	Bal.	
A R C	12.	36.	Bal.	W, 2; C, 0.25
Ascoloy:				
33	12–16	0.5	Bal.	Max., Mn, 0.5; Si, 0.5; C, 0.12
44	22–25	10–13	Bal.	Max., Mn, 1; Si, 0.5; C, 0.2
55	26–30	0.6	Bal.	Max., Mn, 1; Si, 0.6; C, 0.25
66	16–19	0.5	Bal.	Max., Mn, 0.5; Si, 0.5; C, 0.12
A T G	10.	60.	26.	W, 4
Bario	21.4	57.4	1.	W, 15.4; C, 0.3
Bario, Sheet	4.25	90.	.....	W, 1.2; Si, 0.3
Borcher's	36.	.....	60.	Mo, 4
Borcher's	65.	.....	35.	
Borcher's	30.	65–67	.....	Au, 0.5–5; Ag, 0.25–5
Borcher's A	30.	65–68	.....	Au, 0.5–5; Ag, 0.25–1.5
Borcher's B	30.	52–68	.....	Au, Bal.; Ag, 0.15–1.5
Brearley	12–14	.....	Bal.	Si, 0.5 max.; C, 0.3
Brearley patent	9–16	.....	.....	C, 0.7 max.
B T G	12.	60.	Bal.	Mn, 2; W, 1–4; C, 0.5
Carpenter 3	20.	.....	Bal.	Cu, 1; C, 0.3
Carpenter 5	14.	.....	Bal.	ZrS, 0.4; C, 0.1
Cekas	11.2	59.7	Bal.	Mn, 2
Cobaltcrome	13.6	.....	79.5	Co, 3.7; Mo, 0.84; Si, 0.8; C, 1.5
Cobaltcrome	30–25	.....	70–60	Co, 5–10
Colonial, B	16.5	.....	Bal.	C, 0.65
Colonial, U	19.	9.	Bal.	Cu, 1; Mo, 1; C, 0.2 (Resists Chlorides)
Colville S. Iron	16–17	.....	Bal.	Mn, 0.4; C, 0.1
Contracid	.....	.....	.....	Ni, Cr, Fe Alloys + 10 Mo.
Cooperite	.....	80.	.....	W, 14; Zr, 6
Corrosiron	.....	.....	85.5	(Similar to Duriron). Si, 13.5
Cronite	13.7	63.5	20.3	Mn, 1; Al, 0.8; Si, 0.4
Crucible Stainless Iron:				
12	12–14	.....	Bal.	
18	17–19	.....	Bal.	
24	24–27	.....	Bal.	
Cyclops K	8.	.....	Bal.	W, 8; C, 0.4
Defirust	12–14	.....	Bal.	Max., Mn, 0.5; C, 0.1

STAINLESS AND CORROSION-RESISTING ALLOYS (*Continued*)

	CR	NI	FE	OTHER ELEMENTS AND COMMENTS
Defistain	17–19	7–10	Bal.	Max., Mn, 0.5; C, 0.2
Delhi Hard	16–18	.....	Bal.	Si, 0.75–1; Mn, 0.35–0.5; C, 1–1.1
Delhi	18.	.....	Bal.	Si, 1.5; Mn, 0.3; C, 0.3–0.6
Duke's Metal	11.8	.....	Bal.	Co, 4.7; W, 0.35; Si, 0.6; C, 1.45
Duraloy, A	27–30	.....	Bal.	Mn, 0.5
Duraloy, B	16–18	.....	Bal.	Mn, 0.5
Durimet, A	.....	25.	Bal.	Si, 5; C, 0.25
Durimet, B	12.	35.	Bal.	Si, 5; C, 0.25
Durimet, D	2.5	15.	Bal.	Si, 3; C, 0.6
Duriron	.....	.....	Bal.	Si, 14.5; Mn, 0.35; C, 0.85
Duriron	.....	.....	Bal.	Si, 14–14.5; Mn, 0.25–0.35; C, 0.2–6
Duriron	.....	.....	Bal.	Si, 14–15; Mn, 2–2.5; C, 0.75–1.25
Elcomet	9.	14.5	Bal.	Cu, 11; Mn, 0.3; C, 0.3
Elianite	.....	.....	.....	Similar to Duriron
Elinvar	12.	36.	Bal.	Si, 1–2
Enduro:				
A	16.5–18.5	0.25	Bal.	Mn, 0.5; Si, 0.5–1.25; C, 0.1
S	12.5–14.5	0.25	Bal.	Mn, 0.5; Si, 0.5; C, 0.05–0.12
S, 15	12.5–14.5	0.5+	Bal.	Mn, 0.5; Si, 0.5; C, 0.12–0.18
K A 2	16.5–19.5	7–10	Bal.	Mn, 0.5; Si, 0.75; C, 0.15
Era, ATV	13.4	22.6	Bal.	W, 3.3; Mn, 1.5; Si, 1.8
Era, HR	18.2	7.	Bal.	W, 3.7; Mn, 0.56; Si, 1.4
Fermet	4.	18.	Bal.	Mn, 2.2; W, 1; Cu, 0.3; C, 0.35
Fibrite	17.	35.	Bal.	
Field, Rolled	.....	60.	20.	Mo, 20
Field, Cast	.....	Bal.	.....	Si, 10; Cu, 3; Al, 1.5–2
Hastelloy:				
A	.....	60.	20.	Mo, 20
	.....	58.	20.	Mo, 20; Mn, 2
D	.....	85.	.....	Si, 10; Cu, 3; Al, 1.5–2
C	14.	58.	6.	Mo, 17; W, 5
Hascrome	10–12	.....	Bal.	Mn, 3–4; C, 1.0
Haynes Patent	8–60	.....	Bal.	C, not over 1 per cent
Haynes Metal	20–30	.....	Bal.	Co, 5–2.5
Illium	21.	62.5	1.	Cu, 6.5; Mo, 5; W, 2; Mn, 1; Al, 1
Illium G	21.	62.5	.....	Cu, 7
Ironac	.....	.....	.....	Similar to Duriron
Konel	.....	70.	6.5	Co, 17.5; Ti, 2.5; Mn, 0.2
Krupp:				
V 1 M	14.	1.75	Bal.	C, 0.2
V 2 A. Nirosta	20.	7.	Bal.	C, 0.2
V 5 M	14.	0.75	Bal.	C, 0.2 (Replaced V 1 M)
V 3 M. Cutlery	14.	0.5	Bal.	C, 0.4
V 4 A. (Sulfurous Acid)	20.	7.	Bal.	Mo, 2.5; C, 0.2
V 6 A. (Am. Chloride)	20.	7.	Bal.	Cu, 2.5; C, 0.2
K A 2. (High Temp.)	16–20	7–10	Bal.	Max., Si, 0.75; Mn, 0.5; C, 0.15
Ludlum Enduro K M I	12–14	2 max.	Bal.	Max., C, 0.12; Mn, 0.3–0.6
McFarland & Harder	10.	48.	.....	Cu, 43
McFarland & Harder	16.	29.	.....	Cu, 55
McFarland & Harder	30.	59.	.....	Cu, 11
McFarland & Harder	43.	46.	.....	Cu, 11
Midvale:				
V 2 A	17–19	8–9	Bal.	Mn, 0.5, max.; C, 0.06–0.25
H R	20.	7.	Bal.	W, 4; Mn, 0.5; C, 0.35
A T V 1	10–12	33–39	Bal.	Mn, 1.1–1.8; C, 0.25–0.35
A T V 3	13–15	25–28	Bal.	W, 3–4; Mn, 1–1.25; C, 0.4–0.5
B T G	10–11	60–62	Bal.	W, 2–2.5; Mn, 1.2–1.5; C, 0.3–0.35
Misco C	28–30	8–10	Bal.	Si, 1.5; Mn, 0.4–0.5; C, 0.5–0.7
Misco Standard	15–17	35–37	Bal.	Si, 1.4–1.6; Mn, 0.6–0.8; C, 0.5–0.7
Nevastain	9.5	.....	Bal.	Si, 3.8; C, 0.43

STAINLESS AND CORROSION-RESISTING ALLOYS (*Continued*)

	Cr	Ni	Fe	Other Elements and Comments
Nichroloy	7.	40.	50.	Mn, 3
Nichroloy	16.	75.	8.	Mn, 3
Nichroloy, cast	20.	23.	50.	Mn, 1 (Al, Si, V, C.)
Nichrome	.....	.....	.....	
Non-Corrodite No. 25	22.2	0.4	Bal.	Si, 1.57; Mn, 1; Cu, 0.15; C, 0.34
Parr	15.	80.	.....	Cu, 5
Parr	18.	66.6	.....	Cu, 8.5; W, 3.3; Al, 2; Mn, 1; Ti, 0.2; B, 0.2
Rezistal:				
2 - K A	17–19	7–10	Bal.	Si, 1, max.; C, 0.15
2 - C	17–19	7.10	Bal.	Si, 2–3; C, 0.20
4	16–18	24–26	Bal.	Si, 2.5–3; C, 0.20
7 - K	24–26	14–16	Bal.	Si, 1.5–2; C, 0.25
255 - C	10–12	24–26	Bal.	Si, 4.5–5.5; C, 0.25
2600	8–10	21–23	Bal.	Si, 1.2–1.7; C, 0.4
355 - C	10–12	33–35	Bal.	Si, 4.5–5.5; C, 0.25
2 - A	17.3	9.	Bal.	Si, 0.57; C, 0.11
7	26.33	21.2	Bal.	Si, 1.54; C, 0.22
Rohn (Best)	15.	61.	15.	Mo, 7; Mn, 2
Sea Water	1.2	24.	Bal.	Mn, 0.6; Si, 0.35; C, 0.5
Sea Water	.....	16.7	Bal.	Mn, 5; Si, 0.3; C, 0.7
Sideraphite	.....	23.	63.	Cu, 5; Al, 5; W, 4
Siemens-Halske, 1	.....	90–95	.....	Ta, 5–10
Siemens-Halske, 1A	.....	70.	.....	Ta, 30
Silchrome	9.3	0.22	Bal.	Si, 2.92; C, 0.41
Silchrome	9.5	.....	Bal.	Si, 4; C, 0.5
Silchrome, wire	18.	.....	Bal.	Si, 3; W, 3; C, 0.3
Strauss Patent	6–25	20–0.5	Bal.	C, 1, max.
Staybrite	18.	8.	Bal.	
Sterling Nirosta	18.	8.	Bal.	Mn, 0.35; C, 0.15
Sterling Stainless A	13.5	.....	Bal.	Mn, 0.35; C, 0.35
Sterling Stainless B	16.5	.....	Bal.	Mn, 0.35; C, 0.65
Sterling Stainless T	12.5	0.35	Bal.	Mn, 0.35; C, 0.12
Sweetaloy:				
16	16–18	0.5	Bal.	Mn, 0.5; C, 0.35
17	10.	22.	Bal.	Mn, 0.5; C, 0.2
19	28.	0.5	Bal.	Mn, 0.5; C, 0.5
20	18.	36.	Bal.	Mn, 0.5; C, 0.3
22	28.	10.	Bal.	Mn, 0.5; C, 0.35
Tantiron	.....	.....	Bal.	Si, 13.5; Mn, 0.4; P, 0.18; C, 1.0
Uniloy Spec. 1	18.	8.	.....	C, 0.2
Uniloy 1809	18.	0.5	.....	C, 0.09
Zorite	15.	35.	Bal.	Mn, 1.75; C, 0.5

COBALT ALLOYS, TOOLS, CORROSION RESISTING, HEAT RESISTING, ETC.

	Co	Cr	W	Ni	Fe	Other Elements and Comments
A. T. V.	34.	11.4	.....	33.9	Bal.	Mn, 1.1; C, 0.28
Bario, soft	60.	20.	20.	.....	.....	
Bario, hard	30.	30.	25.	.....	.....	Mn, 10; Ti, 5
Block's Alloy	54.	.....	.....	45.	.....	Si, 0.9
Borcher's	35.	30.	.....	35.	.....	
Borcher's	34.	30.	.....	34.	.....	Ag, 2
Borcher's	35.	30.	.....	35.	.....	Mo, 0.5–5
Clamer's	5–25	.....	.....	25–50	Bal.	
Cobaltcrome	3.7	13.6	.....	.....	79.5	Mo, 0.84; Si, 0.8; C, 1.5
Cobaltcrome	5–10	30–25	.....	.....	70–60	
Haynes	5–25	20–30	.....	.....	Bal.	
Haynes, hard	45.	15.	40.	.....	.....	
Haynes, soft	62.	10.	28.	.....	.....	

COBALT ALLOYS, TOOLS, CORROSION RESISTING, HEAT RESISTING, ETC. (*Continued*)

	Co	Cr	W	Ni	Fe	Other Elements and Comments
Schulz (chem. resistant)	31.	15.	35.	.....	2.	Mo, 10; C, 0.7
K. S. Magnet	39.3	2.44	6.36	.....	Bal.	Mn, 0.35; Si, 0.12; C, 0.54
K. S. Magnet	30–40	1.5–3	5–9	.....	Bal.	C, 0.4–0.8
Stellite	40–55	15–33	10–17	.....	0.5	C, 2 or more
Stellite Tools	45.	30–35	17–18	.....	.....	C, 2.75
Stellite German	19.8	26.4	8.7	18.5	11.	V, 9; Mo, 4.4; Si, 0.9; C, 0.9
Stellite	75.	25.	.....	.....	.....	
Stellite	70.	25.	5.	.....	.....	
Stellite	60.	15.	25.	.....	.....	
Stellite	55.	15.	25.	.....	.....	Mo, 5
Stellite	45.	15.	.....	.....	.....	Mo, 40
Stellite	55.6	33.6	9.2	.....	.....	C, 1.5
Stellite	34.5	26.4	12.5	.....	10.	Mo, 9.5; C, 1.8
Stelliting Rod	60.4	30.4	4.26	0.5	1.	Si, 1.36; C, 1.32
Stelliting Rod	57.9	29.6	6.85	0.43	2.2	Si, 1.08; C, 1.33
Stelliting Rod	56.	28.2	11.2	0.4	0.7	Si, 0.35; C, 1.22
Akrit	38.	30.	16.	10.	.....	Mo, 4; C, 2–5
Akrit	37.9	28.1	15.1	9.1	2.2	Mo, 3; Si, 0.9; V, 0.15; C, 3.88
Stoodite	1.4	32.8	.....	0.2	53.8	Mn, 1.2; Si, 0.38; C, 4.05
Stellite:						
Haynes No. 1	48–52	28–32	10–15	.....	.....	
Haynes No. 3	48–53	28–32	12–16	.....	.....	
Haynes No. 6	63–68	27–30	2–6	.....	.....	
Haynes No. 12	52–58	30–34	6–10	.....	.....	
Deloro No. 4	45–50	25–30	15–20	.....	.....	C, 2.5–2.75
Celsit, similar to Stellite	.....	.....	.....	.....	.....	
Percit, similar to Stellite	.....	.....	.....	.....	.....	
Metalline	35.	.....	.....	.....	10.	Cu, 30; Al, 25

CUTTING TOOLS, DIES, ETC. HARD ALLOYS

	Elements and Comments
Blackor (facing)	Tungsten Carbide, W_2C
Carboloy I	Tungsten Carbide + 8 per cent Co
Carboloy II	Tungsten Carbide + 13 per cent Co
Diamonite	W, 95.65; C, 3.91 ($W_2C + WC$)
Elmarid	W, 85; Co, 4.5; Fe, 0.4; C, 5.9 ($W_2C + WC$)
Firthite	
Lohmanit	Tungsten Carbide with a small percentage of Molybdenum Carbide
Thoran	W, 95.85; C, 3.94 ($W_2C + WC$)
Volumit	Tungsten Carbide with a small percentage of Molybdenum Carbide
Widia	W, 86.4; Co, 6.1; C, 5.68 (WC)
Walramite	Tungsten Carbide ($W_2C + WC$)
High Speed Tool	Ni, Bal.; W, 5–12; Ti, 6–12; Si, 3–6; Al, 3–5; B up to 1
High Speed Wissler	Ni or Co, 15–50; W, 15–35; Cr, 15–40; B, 0.5–2.5; C, 0.75–2.5
New Tool Steel Cast	Ni, 58; Zn, 20; Al, 12; Si, 10
Tizit	W, 40–84; Fe, 3–40; Ti, 4–15; Cr, 4; Ce, 1–5; C, 2–4
Akrit	
Stellite	

PYROPHORIC ALLOYS (BUDGEN)

	Elements and Comments
Auer Metal	Ce, 35; La, 24; Yt, 3; Erb, 2; Fe, 35
Cheap "Auer"	Fe, 53; Mn, 30; Sb, 10; Misch Metal, 7
Kunheim	Mg, 12; Al, 2; H, 2; combined with 86 per cent rare earths as hydride
Misch Metal	Alloys from residues from thorium nitrate factories
———	Fe, 61; Cr, 20; Ti, 12; Mn, 7

REFERENCES ON COMPOSITIONS OF ALLOYS

1. Bischoff, "Das Kupfer und Seine Legirungen" (1865).
2. Bolley, "Recherches Chimiques" (1869).
3. Brannt, "The Metallic Alloys" (1908).
4. Buchanan, "Practical Alloying" (1910).
5. Guillet, "Études Industrielle des Alliages Metalliques" (1906).
6. Guettier, "Guide Practique des Alliages (1865).
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8. Herve, "Alliages Metalliques."
9. Hiorns, "Mixed Metals of Metallic Alloys" (1912).
10. Krupp, "Die Legirungen" (1890), (1906).
11. Law, "Alloys and Their Industrial Applications" (1914).
12. Ledebur, "Die Metallverarbeitung auf Chemisch-physikalischen Wege."
13. Roberts-Austen, "Introduction to Metallurgy."
14. Thurston, "Brasses, Bronzes and Other Alloys (III. Materials of Engineering)" (1897).
15. Kaiser, "Zusammensetzung der Gebrauchlichen Metallegierungen," *Metallurgie*, VIII, pp. 257–296 (1911).
16. Metals and Alloys, *Metal Industry*, London (1918) (1929).
17. Wood, R. A., "The Waterbury Book of Alloys."
18. "International Critical Tables," Vol. II (1927).
19. International Nickel Co. "Nickel Bearing Alloys" (1929).

REPORT OF COMMITTEE B-3
ON
CORROSION OF NON-FERROUS METALS AND ALLOYS

During the past year, Committee B-3 has been very active through its Advisory, Finance, Materials and other subcommittees.

Through the activities of the Finance Committee, jointly with Subcommittee XV on Die-Cast Metals and Alloys of Committee B-2 on Non-Ferrous Metals and Alloys, approximately $10,225 has been subscribed to the funds for carrying on the corrosion work of the two committees.

The subcommittee in charge of the work of obtaining various materials for tests and exposure at the various outdoor locations has been quite active. Approximately 13,000 tension test specimens representing the many different materials to be tested have been obtained and machined in accordance with the requirements of the many tests of the various subcommittees. Approximately 10,000 other specimens representing also many different kinds of materials have been obtained.

A reserve supply of each type of material has been forwarded to the U. S. Bureau of Standards for storing so as to be available for future reference.

Subcommittee I on Total Immersion Test (H. A. Bedworth, chairman).—This subcommittee has done no active work during the past year as the personnel has been cooperating with other subcommittees in obtaining materials and in getting the long-time service tests started. Materials have been received from nearly all of the cooperating producers for further tests by Subcommittee I, and as soon as the long-time tests are under way, this subcommittee will again take up the work of laboratory tests.

Subcommittee VI on Atmospheric Corrosion (W. H. Finkeldey, chairman).—The erection of the galvanized structural steel test racks has been completed at all of the test locations as follows:

Key West, Fla.—U. S. Navy Department;
Sandy Hook—Fort Hancock;
Altoona, Pa.—Pennsylvania Railroad Co.;
New York City—Bell Telephone Laboratories, Inc.;
Rochester, N. Y.—Rochester Gas and Electric Corp.;
State College, Pa.—Pennsylvania State College;
Pittsburgh, Pa.—Brunot's Island Power Station, Duquesne Light Co.

The small galvanized specimen racks on which will be mounted the 9 by 12-in. plates and the tension test specimens have all been finished and shipped to the various test locations. The necessary bolts, nuts, enameled iron rods, porcelain insulators, phenol fiber spacer tubes have either been shipped to the test locations or are on hand ready for distribution as soon as the test specimens are shipped to the exposure locations.

All the metals and alloys to be used in these tests have been received from the various companies supplying these materials. The machining of the tension test specimens has been completed on all materials with the exception of aluminum bronze, commercial lead, 1-per-cent antimony-lead alloy, commercial tin and manganese bronze. Work on these materials is now in progress and their delivery is promised by the end of March.

The 9 by 12-in. plates of all the metals and alloys to be used in these tests are now on hand at the U. S. Bureau of Standards, where they have been weighed on a special balance purchased by the committee.

A complete list of all the materials to be used in the atmospheric corrosion tests appears in the following tabulation:

Material	Identification Letter	Supplier	Tension Tests to Be Made by
Commercial Copper (Tough Pitch)	A	American Brass Co	American Brass Co.
Commercial Copper (Phosphorized)	B	American Brass Co	Chase Metal Works
Copper-Silicon-Manganese Alloy (Everdur)	C	American Brass Co	American Brass Co.
Tin Bronze	D	American Brass Co	Scovill Manufacturing Co.
Aluminum Bronze	F	American Brass Co	Bridgeport Brass Co.
Commercial Aluminum	G	Aluminum Company of America	Aluminum Company of America
Aluminum-Manganese Alloy	I	Aluminum Company of America	Aluminum Company of America
Manganese Bronze	K	American Manganese Bronze Co.	American Manganese Bronze Co.
Brass (85–15)	L	Bridgeport Brass Co	Bridgeport Brass Co.
Admiralty Metal	N	Scovill Manufacturing Co	Scovill Manufacturing Co.
Brass (70–30)	M	Chase Metal Works	Chase Metal Works
Duralumin	O	Aluminum Company of America	Aluminum Company of America
Copper-Nickel-Zinc Alloy (Ambrac)	P	American Brass Co	American Brass Co.
Copper-Nickel-Tin Alloy (Adnic)	Q	Scovill Manufacturing Co	Scovill Manufacturing Co.
Monel Metal	G	International Nickel Co	International Nickel Co.
Commercial Nickel	T	International Nickel Co	International Nickel Co.
Chemical Lead	U	National Lead Co	National Lead Co.
Aluminum-Magnesium-Silicon Alloy	Z	Aluminum Company of America	Aluminum Company of America
Commercial Zinc (Prime Western)	AA	New Jersey Zinc Co	New Jersey Zinc Co.
Commercial Zinc (High Grade)	BB	New Jersey Zinc Co	New Jersey Zinc Co.
Lead-Antimony Alloy	CC	National Lead Co	National Lead Co.
Commercial Tin	EE	National Lead Co	National Lead Co.
Alclad	FF	Aluminum Company of America	Aluminum Company of America
Bunker Hill Zinc	HH	St. Joseph Lead Co	St. Joseph Lead Co.

The work of measuring all the tension test specimens before they are exposed on the rack and making the initial tensile strength tests is now in progress in the laboratories of the suppliers of the materials. Each supplier has agreed to test the materials it has furnished with the exception of the American Brass Co., which company has furnished six of the metals and alloys used in this test and is testing three; the remaining materials will be tested by other companies having a common interest in this investigation.

The mounting of the exposure test specimens on the racks at the various test locations will be handled by a field test committee. It is expected that all specimens will have been placed on the racks by the end of May. The work of mounting these specimens on the racks at Key West, Fla., will be handled through arrangements made with members of the U. S. Navy Department stationed there.

Subcommittee VII on Corrosion in Liquids (R. J. McKay, chairman).—No important changes have been made in the plans for this subcommittee during the year. Progress has been made in obtaining samples and it is expected that all samples will be in the hands of the operators of tests in a short time. Tests will be started immediately after receipt of the samples. A substitution has been made in one of the materials to be tested, namely a chromium-nickel-iron alloy was substituted for one of the aluminum bronzes.

Subcommittee VIII on Galvanic and Electrolytic Corrosion (C. L. Hippensteel, chairman).—The program of this subcommittee as outlined in previous reports has not been changed except that it has been agreed to extend the list of metal couples to be tested in outdoor exposure to include all of the metals listed in the 1928 report.[1]

In its annual report to the Society made in 1926,[2] this committee had occasion to refer to the enormous amount of work which had already been done for it by various cooperating laboratories and suppliers of materials. Since that time, considerably more work, large quantities of material, considerable time and cash have been contributed. The committee wishes to thank all of the contributing companies and individuals for their cooperation.

The following firms and individuals have contributed a total of about 2400 days at an estimated total expense, including salaries and overhead, of $148,000, have supplied materials valued at $3175, constructed special testing equipment at a cost of $8845 and have made cash contributions of $5375 to the work of Committee B-3:

Ajax Metal Co.
Allegheny Steel Co.
Aluminum Company of America
American Brass Co.
American Manganese Bronze Co.
American Mond Nickel Co.
R. J. Anderson
Bell Telephone Laboratories, Inc.
Bridgeport Brass Co.
Bureau of Engineering, U. S. N.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 223 (1928).

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 194 (1926).

William Campbell
Chapman Valve Co.
Chase Metal Works
Chemical Warfare Service
Consolidated Gas Co. of New York
W. M. Corse
Damascus Bronze Co.
De Laval Separator Co.
Doehler Die Casting Co.
Duquesne Light Co.
E. I. du Pont de Nemours & Co.
The Duriron Co.
Eastman Kodak Co.
Engineering Division, U. S. Air Service, McCook Field
Fairmont Manufacturing Co.
Federal Mogul Co.
General Electric Co.
International Harvester Co.
International Nickel Co.
Lehigh Valley Coal Co.
Lucius Pitkin, Inc.
Lumen Bearings Co.
Lunkenheimer Co.
C. H. Mathewson
National Canners' Assn.
National Lead Co.
New Jersey Wire Cloth Co.
New Jersey Zinc Co.
New York Edison Co.
Philadelphia & Reading Coal & Iron Co.
Raritan Copper Works
Research Laboratory of Applied Chemistry, Massachusetts Inst. of Technology
D. P. Robinson and Co., Inc.
Rochester Gas & Electric Co.
Samuel P. Sadtler and Son, Inc.
St. Joseph Lead Co.
M. F. Sayre, Union College
Scovill Manufacturing Co.
Singmaster & Breyer
Sloan Valve Co.
Stanley Works
Swift and Co.
Sam Tour
U. S. Bureau of Mines
U. S. Bureau of Standards
U. S. Naval Gun Factory
U. S. Naval Engineering Exp. Station
U. S. Shipping Board, Emergency Fleet Corp.
Vanadium Corporation of America
Western Electric Co.
Westinghouse Electric and Manufacturing Co.

The following firms have made cash contributions totaling about $4850 to the fund of the joint corrosion investigations of Committee B-3 and of Subcommittee XV on Die-Cast Metals and Alloys of Committee B-2 on Non-Ferrous Metals and Alloys:

Allis-Chalmers Manufacturing Co.
American Zinc Institute
Apex Smelting Co.
Automatic Electric Co.
British Aluminum Co.
Byllesby Engineering and Management Corp.
Copper and Brass Research Assn.
Crane Co.
Crucible Steel Co. of America
Detroit Edison Co.
Henry L. Doherty and Co.
Evans-Wallower Zinc Co.
Grasselli Chemical Co.
International Silver Co.
Latrobe Electric Steel Co.
Madison-Kipp Corp.
Milwaukee Die Casting Co.
National Cash Register Co.
National Smelting Co.
Northern Electric Co.
Ohio Brass Co.
Packard Motor Car Co.
Riverside Metal Co.
Solvay Process Co.
Speakman Co.
Stewart Die Casting Co.
Sun Oil Co.
Tallman Brothers
Tillotson Manufacturing Co.

Union Carbide and Carbon Research Laboratories
United Metals Selling Co.
Western Union Telegraph Co.
Wolverine Tube Co.
Yale and Towne Manufacturing Co.

If some firms or individuals have been omitted from these lists, it has been an inadvertence.

This report has been submitted to letter ballot of the committee, which consists of 40 members; 32 member returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

T. S. FULLER,
Chairman.

SAM TOUR,
Secretary.

REPORT OF COMMITTEE B-4

ON

ELECTRICAL-HEATING, ELECTRICAL-RESISTANCE AND ELECTRIC-FURNACE ALLOYS

Two meetings of the committee have been held during the year, as follows: on September 26 and 27, 1929, at Detroit, Mich.; on February 17 and 18, 1930, in New York City.

Seven members have been added to the committee during the year, leaving the total membership 27, classified as 12 non-producers, 12 producers, and 3 general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Proposed Tentative Standard.—A Proposed Method of Test for Thermoelectric Power, to determine the thermoelectric power of materials with respect to copper when the temperature of the junctions lies between 0 and 100° C., is recommended for publication as a tentative standard as appended hereto.[1] It is intended for materials for use in resistance apparatus in which a low thermoelectric power is desired.

Tentative Standard Advanced to Standard.—The committee recommends that the Tentative Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating (B 70 – 27 T)[2] be advanced to standard without revision.

Tentative Standards Continued as Tentative.—The committee recommends that the following tentative standards be continued as tentative for another year without revision:

Tentative Methods of Chemical Analysis of Metallic Materials for Electrical Heating (B 71 – 29 T);

Tentative Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 – 29 T).

GENERAL COMMITTEE ACTIVITIES

Coordination of the activities of Committee B-4 and of Committee A-10 has been the subject of several conferences between representatives of the two committees and members of the Executive Committee of the Society. After careful consideration, it has been decided to change the title of Committee B-4 to read "Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys." The scope has been defined as: "Wrought and cast materials and parts for electrical heating and electrical resistance, and for the structure and containers of electric furnaces."

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[1] See p. 1013.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 757 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 183.

The title of Committee A-10 is: "Iron-Chromium, Iron-Chromium-Nickel, and Related Alloys," and its scope: "Alloys as defined in title, not falling within the described scope of Committee B-4."

At the request of the Executive Committee, a joint Advisory Committee of Committees B-4 and A-10 has been organized. The chairman and secretary of Committee B-4 have been appointed to represent the committee on this advisory committee.

In order to maintain contact between Committee B-4 and the Joint Research Committee of the A.S.M.E. and A.S.T.M. on the Effect of Temperature on the Properties of Metals, Mr. P. H. Brace has been elected an associate member of the joint committee, representing Committee B-4. He has been made chairman of the Subcommittee on Elastic Properties of Metals at High Temperatures.

At the request of Committee E-10 on Standards, that every standing committee have an editorial committee to review all specifications before they are submitted to the Society for adoption, Mr. H. L. Curtis of the Bureau of Standards has been appointed to act in this capacity.

Two new subcommittees have been organized during the year: namely, Subcommittee V on Wrought and Cast Alloys for High-Temperature Use and Subcommittee VI on Specifications for Electrical Heater Wires. Subcommittee V is working on methods of test for materials for use in electric furnaces and Subcommittee VI is preparing material specifications for electrical heating wires.

At the request of the Secretary-Treasurer, the committee considered the subject of the data on electrical-heating and electrical-resistance wires given in the Symposium on Corrosion-Resistant, Heat-Resistant, and Electrical-Resistance Alloys issued in 1924.[1] It was found that the symposium mentioned practically all of the items needed on these alloys. The committee recognized that the symposium was the response to a real need for data and was to be commended, but the suggestion was made that future collections of data on this subject published by the Society should be according to recognized standard methods of testing so that data from different sources can be compared.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 189 (1924).

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Life Tests (J. W. Harsch, chairman).—In order to determine the relation of the life of electrical heating wires as shown by the Tentative Accelerated Life Test for Metallic Materials for Electrical Heating (B 76 – 29 T) and the life of the same wire under a particular service condition, a series of comparative tests is being made. Two lots of wire, having short and long lives, respectively, by the accelerated life test, are being used. Each lot is being tested by the accelerated life test and also in radiant electric toaster units with current cycle 2 minutes on and 2 minutes off as in the life test. Four laboratories will make the accelerated life tests and four will make the tests in the toaster units.

The question of extending the accelerated life test to allow larger sizes of wire to be tested is being studied.

The effect of atmospheric humidity upon the length of life obtained in the accelerated life test is being determined by making tests under different conditions of humidity.

Subcommittee II on Electrical Tests (H. L. Curtis, chairman).—During the year the Proposed Method of Test for Thermoelectric Power, appended hereto,[1] for determining thermo electric power of materials with respect to copper has been developed and is being submitted to the Society as a tentative standard.

The method of test for thermoelectric power has been used in several laboratories. In two laboratories the thermoelectric power of several samples was measured by the proposed method and by a more elaborate method designed to give higher accuracy. The results by the proposed method have in every case been at least as accurate as were expected.

An extensive investigation of a method of test for temperature coefficient of resistance has been carried on. A test method has been outlined which will be tried by seven laboratories.

Subcommittee IV on Mechanical Tests (P. H. Brace, chairman).—A bend test for determining the elastic properties of alloys at temperatures from 500 to 1000° C. has been outlined.

Devices for constraining thin specimens while they are being heated to various temperatures have been developed, also means of accurately determining the curvature before and after heating. This equipment permits a study to be made of the permanent bending of a given material over a wide range of maximum strain and temperature. The results will be compared with tension tests on the same material. Several laboratories are cooperating in making the tests.

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[1] See p. 1013.—ED.

Subcommittee V on Wrought and Cast Alloys for High-Temperature Use (H. W. McQuaid, chairman).—A study is being made of alloys used for electric furnace structures and containers to develop methods of test for the properties which are important for these applications. Mr. C. L. Clark of the University of Michigan presented a discussion before the subcommittee of the causes of warpage. Tension and compression test methods are being prepared, also methods of test for temperature coefficient of expansion and thermal conductivity.

Subcommittee VI on Specifications for Electrical Heater Wire (J. W. Harsch, chairman).—Material specifications are being prepared for the nickel-chromium and iron-nickel-chromium alloys now being used for electrical heating wires.

The recommendations in this report have been submitted to letter ballot of the committee, which consists of 27 members, with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED TENTATIVE STANDARD			
Proposed Tentative Method of Test for Thermoelectric Power	18	0	6
II. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Tentative Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating (B 70 – 27 T)	21	0	1

This report has been submitted to letter ballot of the committee, which consists of 27 members; 24 members returned their ballots, of whom 22 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

DEAN HARVEY,
Chairman.

F. E. BASH,
Secretary.

EDITORIAL NOTE

The proposed Tentative Method of Test for Thermoelectric Power was accepted for publication as tentative and appears on page 1013.

The Tentative Method of Test for Change of Resistance with Temperature of Metallic Materials for Electrical Heating was approved at the annual meeting and was subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appears in the 1930 Book of A.S.T.M. Standards, Part I, page 872.

REPORT OF COMMITTEE B-5

ON

COPPER AND COPPER ALLOYS, CAST AND WROUGHT

Committee B-5 held one meeting during the past year in New York City in February.

The unbalanced distribution of membership between producers and other interests referred to in last year's report has been rectified and the total membership is now 48 classified as 23 producers, 18 consumers and 7 general interests.

At a meeting held in connection with the annual meeting of the Society in June, 1929, Mr. D. K. Crampton was elected Secretary to succeed Mr. N. L. Mochel, resigned.

At the request of Committee E-10 on Standards that every standing committee have an Editorial Committee to review all specifications and methods of test before they are submitted to the Society for adoption, the chairman and secretary of Committee B-5 have been appointed in this capacity.

Mr. D. K. Crampton was appointed as a representative of Committee B-5 on the Coordinating Committee on Non-Ferrous Metals and Alloys in place of the former secretary.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Wrought Metals and Alloys (W. R. Webster, chairman).—No specific demand for new specifications covering the field of wrought copper and copper alloys has become evident. Subcommittee I has therefore been active principally in reviewing the present specifications and undertaking such minor revisions from time to time as will keep them up to date and make them more acceptable. This subcommittee is recommending, as mentioned later in the report, tentative revisions in three standard specifications, the revision of one tentative specification and the advancement to standard of one tentative specification under its jurisdiction.

Subcommittee II on Cast Metals and Alloys (N. K. B. Patch, chairman).—Subcommittee II, on the other hand, is entering upon a period of special activity involving cooperation with the Non-Ferrous Ingot Metal Institute through a subcommittee consisting of Messrs. G. H. Clamer, H. W. Bolton and F. W. Wolf. A thorough study of all specifications for cast non-ferrous metals is contemplated in view of an insistent demand that alloys furnished generally to the trade be classified and reduced to a minimum number of essential types. Attention is also being devoted to the problem of obtaining, through a suitable test procedure, reliable determinations of the physical properties of cast material.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards under its jurisdiction are presented as follows, together with an analysis of the letter ballot vote on each item.

Proposed Tentative Revision of Standards:

Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 29),[1] *Standard Specifications for Seamless 70–30 Brass Condenser Tubes and Ferrule Stock (B 55 – 25)*[2] and *Standard Specifications for Seamless Muntz Metal Condenser Tubes and Ferrule Stock (B 56 – 25).*[2]—The committee recommends that the following schedule of tolerances on length be issued as a tentative revision of these three specifications to replace, when adopted, the present requirements now specified.

The committee recommends that Section 14 of Specifications B 44 – 29, B 55 – 25 and B 56 – 25 be changed from their present form: namely,

> **14.** The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.).

to read as follows:

> **14.** The length shall not be less than that ordered when measured at a temperature of 20° C. (68° F.), but may be more than that ordered by the amounts in the following table:

ORDERED LENGTH, FT.	PERMISSIBLE TOLERANCES, IN.
Up to 15, inclusive	$+\frac{1}{16}$
Over 15 to 20, inclusive	$+\frac{3}{32}$
Over 20	$+\frac{1}{8}$

Proposed Revision of Tentative Standard:

Tentative Specifications for Copper Tubing for Refrigerators (B 68 – 27 T).[3]—It is recommended that these specifications be revised as follows and continued as tentative:

Title.—Change the title from its present form to read as follows by the addition of the italicized words and the omission of those in brackets:

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[1] 1929 Supplement to Book of A.S.T.M. Standards, p. 108.

[2] 1927 Book of A.S.T.M. Standards, Part I, pp. 626, 630.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 725 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 142.

Tentative Specifications for *Seamless* Copper Tubing [for Refrigerators], *Bright Annealed.*

Section 1.—Change this section to read as follows by the addition of the italicized words:

1. These specifications cover annealed copper tubing suitable for use in refrigerators, *oil lines, gasoline lines, etc., where tubing absolutely free from scale and dirt is required.*

Section 5.—Change the requirements for copper and phosphorus contents to read as follows by the addition of the italicized figures and the omission of those in brackets:

Copper, minimum	[99.85] *99.90* per cent
Phosphorus, maximum	[0.15] *0.10* per cent

Section 8.—Change the diameter and wall thickness tolerances in this section to agree with those specified in the Tentative Specifications for Seamless Copper Tubes (B 75 – 28 T) in so far as the range of sizes involved coincides. The revised schedules of tolerances would therefore be as follows:

8. The mean inside and outside diameters and the wall thickness of the tubing shall not vary more than the following amounts from that specified:

MEAN INSIDE AND OUTSIDE DIAMETERS, IN.	PERMISSIBLE VARIATIONS, IN.
Up to 1, inclusive	± 0.0025
Over 1 to 2, inclusive	± 0.003

WALL THICKNESS		
STUBBS GAGE NO.	IN.	PERMISSIBLE VARIATIONS, IN.
Under 14 to 17, inclusive	0.082 to 0.058, inclusive	± 0.004
Under 17 to 20, inclusive	0.057 to 0.035, inclusive	± 0.003
Under 20 to 23, inclusive	0.034 to 0.025, inclusive	± 0.0025
Under 23	Under 0.025	± 0.0025

Section 9.—Change the table of length requirements in this section from its present form: namely,

	PERMISSIBLE VARIATIONS, IN.	
ORDERED LENGTH, FT.	MINUS	PLUS
Up to 10, inclusive	0	$\frac{1}{8}$
Over 10 to 70, inclusive	0	6

to read as follows:

FOR STRAIGHT LENGTHS

	PERMISSIBLE VARIATIONS, IN.	
ORDERED LENGTH, FT.	MINUS	PLUS
Up to 8, inclusive	0	$\frac{1}{16}$
Over 8 to 15, inclusive	0	$\frac{1}{8}$
Over 15 to 20, inclusive	0	$\frac{3}{16}$

FOR COILS

ORDERED LENGTH, FT.	PERMISSIBLE VARIATIONS, IN.	
	MINUS	PLUS
Up to 10	0	2
Over 10 to 20, inclusive	0	3
Over 20 to 40, inclusive	0	6
Over 40 to 80, inclusive	0	12
Over 80	0	24

Advancement of Tentative Standard to Standard:

The committee recommends that the Tentative Specifications for Seamless Copper Tubes (B 75 – 28 T)[1] be advanced to standard without revision.

Tentative Standards Continued as Tentative:

The committee recommends that the Tentative Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (B 30 – 28 T) and for Sand Castings of the Alloy: Copper 80 per cent; Tin 10 per cent; Lead 10 per cent (B 74 – 28 T) be continued as tentative.

The committee also recommends that the tentative revision proposed last year in the Standard Specifications for Bronze Bearing Metal in Ingot Form (B 31 – 21) be continued as tentative.

The election of officers resulted in the re-election of C. H. Mathewson and D. K. Crampton as chairman and secretary, respectively, for a period of two years.

The above recommendations have been submitted to letter ballot of the committee with the following result:

Items	Affirmative	Negative	Not Voting
I. PROPOSED TENTATIVE REVISION OF STANDARDS			
Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock (B 44 – 29)	22	0	7
Specifications for Seamless 70–30 Brass Condenser Tubes and Ferrule Stock (B 55 – 25)	22	0	7
Specifications for Seamless Muntz Metal Condenser Tubes and Ferrule Stock (B 56 – 25)	22	0	7
II. PROPOSED REVISION OF TENTATIVE STANDARD			
Specifications for Copper Tubing for Refrigerators (B 68 – 27 T)	24	1	4
III. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Specifications for Seamless Copper Tubes (B 75 – 28 T)	25	0	4

This report has been submitted to letter ballot of the committee which consists of 48 members; 38 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

C. H. MATHEWSON,
Chairman.

D. K. CRAMPTON,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 778 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 144.

EDITORIAL NOTE

The proposed tentative revisions of the Standard Specifications for Seamless Admiralty Condenser Tubes and Ferrule Stock; for Seamless 70-30 Brass Condenser Tubes and Ferrule Stock; and for Seamless Muntz Metal Condenser Tubes and Ferrule Stock were accepted for publication as tentative and appear on page 1272.

The proposed revision of the Tentative Specifications for Copper Tubing for Refrigerators was accepted. The specifications in their revised form appear on page 1010.

The Tentative Specifications for Seamless Copper Tubes were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part I, page 751.

Subsequent to the annual meeting, the committee approved a complete revision of the Tentative Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings in the form of proposed Tentative Specifications for Copper-Base Alloys in Ingot Form for Sand Castings. These proposed revised specifications were approved on August 12 by Committee E-10 on Standards. The specifications in their revised form appear on page 1006.

REPORT OF THE SPECIAL COMMITTEE ON PROMOTION OF GENERAL USE OF SPECIFICATIONS FOR COPPER ALLOYS IN INGOT FORM

The Special Committee on Promotion of General Use of Specifications for Copper Alloys in Ingot Form was organized at a meeting held in Cleveland on November 26, 1928, to consist of representatives of producers, consumers and the trade papers making a practice of giving quotations on copper alloys. Its purpose is to study and promote the use of specifications of copper alloys in ingot form as a basis of price quotations in technical and trade journals with authority to recommend to the appropriate standing committees of the Society such revisions in the A.S.T.M. specifications affected as its studies may indicate to be desirable, particularly with a view toward reducing the number of specific compositions in current use.

A further meeting of the Special Committee has since been held at the Cleveland Athletic Club, December 8, 1929.

Members of the Non-Ferrous Ingot Metal Institute cooperated splendidly with the committee in supplying information concerning the specifications for alloys in ingot form which are at present being used in the industry. Through the office of the Secretary-Treasurer of the Society additional information was supplied concerning specifications of the Society of Automotive Engineers, American Railway Association, the United States Government and the A.S.T.M.

Information was secured, wherever possible, regarding the specific uses of the alloys listed. Further information supplied and tabulated included the tonnage and the number of customers using each alloy. All the supplied information was classified on large sheets under certain definite and arbitrarily chosen classes. Twenty such classes or subdivisions were used, each defined by certain limitations of the main constituents. A second classification was made according to uses. It was found after all duplications were eliminated that there was a net total of 599 alloys reported upon. This list has since been further expanded by reason of adding the alloys listed on belated reports.

In many reports no permissible variations of the constituents of the alloys were given. It therefore became necessary to arbitrarily fix variations on main constituents. The A.S.T.M. tolerances were found to be too close for practical or commercial use and the following variations were, therefore, used:

	PERMISSIBLE VARIATIONS
From 0.00 to 1.00 per cent inclusive......	±50 per cent of the amount specified
" 1.00 to 5.00 " " "	±0.50 " "
" 5.00 to 10.00 " " "	±0.75 " "
" 10.00 to 20.00 " " "	±1.00 " "
" 20.00 to 50.00 " " "	±1.50 " "
Over 50.00 per cent....................	(Balance)

The impurity content wherever given was recorded on the charts. The committee has taken steps to secure further information regarding the uses of the various alloys.

Tabulation of the specifications clearly developed the fact that it is possible to greatly reduce the number of alloys now used in the industry. It was pointed out that there are 40 different specifications for one of the most widely used alloys of the industry, namely, 85 per cent copper, 5 per cent tin, 5 per cent lead and 5 per cent zinc. The variation between the specifications submitted is in all cases slight, either in allowed tolerances on main constituents or on impurity content, namely, nickel, sulfur, phosphorus, iron, antimony, etc. It is certain that these 40 specifications could be condensed into one.

As the Non-Ferrous Ingot Metal Institute had previously pledged its support, the committee recommended that it sponsor an investigation of copper-base ingot metals under the classifications used by the committee in tabulating the data furnished by the Institute, the purpose of the investigation being to supply data upon which to base the further work of bringing about agreement upon an optimum number of compositions of ingot metal and the development of equitable standard specifications covering these compositions. The committee offered its assistance to the Institute in this work and the chairman was authorized to appoint a committee to cooperate with the Institute in carrying on the recommended investigation if desired. The above recommendation was put in the form of a formal resolution and personally presented by the chairman to the Executive Committee of the Non-Ferrous Ingot Metal Institute. The recommendation was approved by the Executive Committee of the Institute and was then formally presented to the meeting of the membership of the Non-Ferrous Ingot Metal Institute in Washington shortly afterward. The resolution had the unanimous support of the membership and it was voted to appropriate $5000 of the Institute's funds for the purpose of carrying out the suggested alloys research program. This appropriation was made to cover one year's work. The chairman and Mr. Robert D. T. Hollowell, Manager of the N.F.I.M.I., were appointed a committee of two to engage a research associate and get the proposed research under way at the National Bureau of Standards, provided the Bureau was in position to undertake the work. The Bureau has signified its willingness and ability to take up the suggested work at this time.

Mr. Harold B. Gardner has been engaged by the Institute as a research associate assigned to the Bureau of Standards to carry on this investigation, under the direction of the Institute. The chairman has appointed a committee consisting of Mr. J. W. Bolton, Mr. F. L. Wolf and himself to advise with the Institute in this work.

In the meantime, Subcommittee II on Cast Metals and Alloys of the Society's Committee B-5 on Copper and Copper Alloys, Cast and Wrought, has been apprised of the fact that the present A.S.T.M. specifications are in need of revision. The question of revision is to be considered at a meeting of the committee to be held during the annual meeting of the Society in June.

Through the work of the special committee there has been developed an opportunity for simplification of practice in regard to the number of specifications in use and the development of more practicable and useful specifications than are in existence at present, and the use of the specifications as a basis for trade paper quotations.

Respectfully submitted on behalf of the special committee,

G. H. CLAMER,
Chairman.

C. L. WARWICK,
Secretary.

REPORT OF COMMITTEE B-7

ON

LIGHT METALS AND ALLOYS, CAST AND WROUGHT

Committee B-7 has been very active during the past year. Although but one regular meeting of the committee has been held since the last annual meeting of the Society, the various subcommittees have diligently carried on their work. Four of these subcommittees have been engaged in the drafting of new tentative standards or in the revision of existing specifications. Subcommittee III is being reorganized for more active work.

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Aluminum and Aluminum-Alloy Ingots (E. H. Dix, Jr., chairman).—This subcommittee has under consideration the preparation of specifications for light alloy hardeners including, aluminum-copper (50:50); aluminum-silicon alloys (75:25 and 70:30); and aluminum-nickel (80:20).

Subcommittee II on Aluminum and Aluminum-Alloy Sheet (R. J. Anderson, chairman).—Proposed Tentative Specifications for Aluminum Alloy (Duralumin) Sheet and for Aluminum-Manganese Alloy Sheet have been prepared by this subcommittee and are recommended for adoption as tentative specifications. These specifications are appended hereto.[1]

This subcommittee is likewise considering the preparation of specifications covering Alclad sheet.

Subcommittee III on Aluminum and Aluminum Alloys, Wrought Shapes Other than Sheet (P. V. Faragher, chairman).—This subcommittee is being reorganized under the supervision of its new chairman.

Subcommittee IV on Aluminum-Base Casting Alloys (V. Skillman, chairman).—The Tentative Specifications for Aluminum-Base Sand-Casting Alloys in Ingot Form (B 58 – 26 T) and Aluminum-Base Alloy Sand Castings (B 26 – 26 T), respectively, are being revised by this subcommittee and it is hoped that they will be in form to submit to Committee E-10 on Standards, at a meeting to be held subsequent to the annual meeting, for publication as tentative.

Subcommittee V on Magnesium and Magnesium-Base Alloys, Cast and Wrought (John A. Gann, chairman).—This subcommittee has prepared proposed Tentative Specifications for Magnesium-Base Alloy Sand Castings[1] which are recommended for publication as tentative.

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[1] See pp. 987 to 992.—ED.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
NEW TENTATIVE STANDARDS			
Tentative Specifications for Aluminum-Alloy (Duralumin) Sheet	14	0	2
Tentative Specifications for Aluminum-Manganese Alloy Sheet	14	0	2
Tentative Specifications for Magnesium-Base Alloy Castings	11	0	6

This report has been submitted to letter ballot of the committee, which consists of 28 members; 20 members returned their ballots, of whom 19 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

J. B. JOHNSON,
Chairman.

JOHN A. GANN,
Secretary.

EDITORIAL NOTE

The proposed Tentative Specifications for Aluminum-Alloy (Duralumin) Sheet; for Aluminum-Manganese Alloy Sheet; and for Magnesium-Base Alloy Castings were accepted for publication as tentative and appear on pages 987, 990 and 1003, respectively.

The proposed revisions of the Tentative Specifications for Aluminum-Base Alloy Sand Castings and for Aluminum-Base Sand-Casting Alloys in Ingot Form referred to in the report were subsequently approved on August 12 by Committee E-10 on Standards. These specifications in their revised form appear on pages 997 and 993, respectively.

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[1] See p. 1003.—ED.

REPORT OF COMMITTEE C-1
ON
CEMENT

During the past year Committee C-1 has held two meetings. At the first of these it seemed desirable to further consider the action of the committee taken at the June, 1929, meeting in reference to changes in the Standard Specifications and Tests for Portland Cement (C 9 – 26)[1] and the adoption of specifications for high-early-strength cements.

As a result of this further consideration, revisions of the present Standard Specifications C 9 – 26 were proposed and included in a report to the Executive Committee of the Society, which report was printed and distributed to the membership of the Society. As a matter of record the revisions are repeated and are as follows:

Section 6.—Change the average tensile strength requirement at 7 days for the three standard mortar briquets from a minimum of 225 lb. per sq. in. to 275 lb. per sq. in., and the average tensile strength requirement at 28 days for the three standard mortar briquets from a minimum of 325 lb. per sq. in. to 350 lb. per sq. in.

Section 28.—Add the following note after this section:

> NOTE.—The balances used in the chemical analysis shall conform to the following requirements: capacity not less than 100 g. in each pan; the two arms of beam to be equal to within one part in 100,000; capable of reproducing results within 0.1 mg.; sensibility reciprocal (see Section 31, Note 1 (3)) not more than 0.2 mg. per division of the graduated scale. The weights used in the chemical analysis shall conform to the requirements of the U. S. Bureau of Standards specifications for Class "S" weights as contained in Bureau of Standards *Circular No. 3.*

Section 31.—Change subnote (3) under Note 1 from its present form: namely,

> (3) Use of a balance which will give results correct within 5 mg. and sufficiently sensitive so that the rest point will be deflected at least two divisions of the scale for an added load of 5 mg.

to read as follows:

> (3) The balance used in making the fineness test shall conform to the following requirements: The balance shall be enclosed in a glass case. On balances in use the tolerance at a load of 50 g. shall be ±0.05 g., and at loads less than 0.1 g. the tolerance shall be ±0.01 g. (The tolerances on new balances shall be one-half of the values given.)

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 23.

The maximum "sensibility reciprocal," allowable at each of the loads specified above shall be twice the value of the tolerance specified for the load in question. The sensibility reciprocal is a measure of the sensitivity of a balance, and is the weight required to move the position of equilibrium of the beam, pan, pointer, or other indicating device of a scale a definite amount at the capacity or at any lesser load. For a complete definition of sensibility reciprocal see U. S. Bureau of Standards *Handbook M 85*, pp. 80–82.

The tolerances in excess or deficiency on the weights in use in the fineness test shall be as follows:

WEIGHT	TOLERANCE	WEIGHT	TOLERANCE
50 g.	0.04 g.	0.500 g.	0.003 g.
20 g.	0.02 g.	0.200 g.	0.002 g.
10 g.	0.014 g.	0.100 g.	0.001 g.
5 g.	0.010 g.	0.050 g.	0.001 g.
2 g.	0.006 g.	0.020 g.	0.001 g.
1 g.	0.004 g.	0.010 g.	0.001 g.

The tolerances on new weights shall be one-half the values given.

Section 33.—Add two additional notes, designated Notes 2 and 3, at the end of this section reading as follows:

NOTE 2.—The scales used in weighing materials for neat cement and mortar mixes shall conform to the following requirements: On scales in use the tolerance at a load of 1000 g. shall be ±1.0 g. (The tolerance on new scales shall be one-half of the value given.) The sensibility reciprocal (see Section 31, Note 1 (3)) shall not be greater than twice the tolerance.

The tolerances in excess or deficiency on the weights in use in weighing materials for neat cement and mortar mixes shall be as follows:

WEIGHT	TOLERANCE	WEIGHT	TOLERANCE
1000 g.	0.5 g.	20 g.	0.05 g.
500 g.	0.35 g.	10 g.	0.04 g.
200 g.	0.20 g.	5 g.	0.03 g.
100 g.	0.15 g.	2 g.	0.02 g.
50 g.	0.10 g.	1 g.	0.01 g.

The tolerances on new weights shall be one-half the values given.

NOTE 3.—Glass graduates of 100-ml. to 200-ml. capacities used for measuring the mixing water shall be made to deliver the indicated volume at 20° C. (68° F.). The tolerance on these graduates shall be ±1.0 ml.

Section 35.—Insert the following at the end of this section:

In addition to the above, the Vicat apparatus shall conform to the following requirements:

Weight of plunger	300 g. ±0.5 g. (0.661 lb. ±8 grains)
Diameter of larger end of plunger	1 cm. ±0.02 mm. (0.394 in. ±0.001 in.)
Diameter of needle	1 mm. ±0.01 mm. (0.039 in. ±0.0005 in.)
Inside diameter of ring at bottom	7 cm. ±3 mm. (2.75 in. ±0.12 in.)
Inside diameter of ring at top	6 cm. ±3 mm. (2.36 in. ±0.12 in.)
Height of ring	4 cm. ±0.5 mm. (1.57 in. ±0.02 in.)

Section 45.—Insert the following at the end of this section:

In addition to the above, the Gillmore needles shall conform to the following requirements:

INITIAL NEEDLE:	
Weight	$\frac{1}{4}$ lb. ±8 grains (113.4 g. ±0.5 g.)
Diameter	$\frac{1}{12}$ in. ±0.001 in. (2.11 mm. ±0.02 mm.)
FINAL NEEDLE:	
Weight	1 lb. ±8 grains (453.6 g. ±0.5 g.)
Diameter	$\frac{1}{24}$ in. ±0.001 in. (1.06 mm. ±0.02 mm.)

Section 47.—Add the following two sentences to this section:

The dimensions of the briquet molds shall conform to the following requirements: width of mold, between inside faces, at waist line of briquet, 1 in. ±0.01 in., thickness of mold 1 in. ±0.004 in. The tolerances on new molds shall be one-half the values given.

Section 52.—Change this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

52. The briquets shall be tested as soon as they are removed from the water. Tests may be made with any machine meeting the following requirements: [The machine shall be capable of weighing the applied load within 0.5 per cent of the nominal value. The sensibility reciprocal (the weight required to be added to the load to move the beam from a horizontal position of equilibrium to a position of equilibrium at the top of the trig loop) shall not exceed 1 lb. at the full capacity of the machine or at any lesser load.] *The error for loads of not less than 100 lb. shall not exceed ±1.0 per cent for new machines or ±1.5 per cent for used machines.* The clips for holding the tension test specimens shall be in accordance with Fig. 7. The bearing surfaces of the clips and briquets shall be free from sand or dirt, and the roller bearings shall be well oiled and maintained so as to insure freedom of turning. The briquets shall be carefully centered in the clips and the load applied continuously at the rate of 600 lb. *±25 lb.* per minute.

Section 55.—Add the following sentence at the end of this section:

The relative humidity of the moist closet shall not be less than 90 per cent.

The committee recommends these revisions for immediate adoption and asks for the necessary nine-tenths vote.

At this same meeting it was also voted to refer immediately to the Executive Committee of the Society, the proposed tentative standard for high-early-strength cement, for reference to the new Committee E-10 on Standards. It was requested that these be considered for immediate publication as tentative[1]. The specifications were accepted by Committee E-10 and issued as tentative. These also have been before the membership of the Society in printed form for about four months. The committee recommends that they be continued as tentative as appended hereto.[1]

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[1] In submitting these specifications to Committee E-10, the committee reported the results of the letter ballot vote as follows: 56 members returned their ballots of whom 47 voted affirmatively and 4 negatively.

At the second meeting of the committee, proposed revised specifications for natural cement and a new specification for masonry cement were brought up for discussion. However, both of these items were referred back to the subcommittee, where they had originated, for further consideration. But the study of these specifications by the committee and those directly interested in these cements brought out the wide and increasing interest that has been developed in them. It was found that 23 different manufacturers are now making a plastic cement for the setting of masonry. This fact coupled with the fact that the committee has but a small representation in its membership of these large groups of producers, led it to invite requests for membership from those interested in the cements.

The chairman of the Subcommittee on Masonry Cements has circularized those making this commodity to obtain certain information regarding the character of the product. This it was thought would be of interest to the general public. The nature of the questionnaire and the answers received are given in Table I. Twenty-three producers were addressed and replies were received from fifteen. The wide variation in the character of the cement and in the properties indicated for these in the replies, are cogent arguments why there should be a standard for this commodity.

The Cement Reference Laboratory, operated jointly by Committee C-1 and the Bureau of Standards, has now been in operation for approximately a year. The work that has been accomplished and some brief reference as to how the efforts of the laboratory are being received, are presented in the report of Subcommittee XIV appended hereto. The impression which may be obtained from this of the helpful way in which the work of the laboratory is being received could be made more vivid by citing many of the letters of appreciation which have been received from those who have had their laboratories inspected. But this would hardly be of as much benefit to the committee as some brief references of a constructive and critical nature which have been received regarding our standard methods.

These criticisms clearly show that the wording of the standard test procedures is quite broad, in too many cases allowing of several apparently proper interpretations.

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[1] See p. 1016.—ED.

TABLE I.—INFORMATION SUPPLIED BY THE MANUFACTURERS ON CHARACTERISTICS OF MASONRY CEMENTS.

Brand	Residue on No. 200 Sieve, per cent	Time of Setting				Chemical Composition, per cent						Loss on Igni-tion, per cent	Weight per Cubic Foot, lb.	Pack-age Weight, lb.	Tensile Strength, lb. per sq. in.				Compressive Strength, lb. per sq. in.			Constituents
		Initial		Final																		
		Hours	Min-utes	Hours	Min-utes	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3				1 day	3 days	7 days	28 days	3 days	7 days	28 days	
No. 1..	5.0	4	00	9	00	35.78	20.18		34.70	2.57	0.89	.....	75	...	...	...	125	225	...	500	1000	Silicates of lime, aluminate of lime. gypsum
No. 2..	14.0	2	50	5	30	.....	.....	....	.....	....	....	.....	67	..	...	...	140	250	...	900	1200	Gray portland cement, pulverized limestone, aquagel
No. 3..	14.0		45	12	00	33.62	11.80		48.20	1.72	0.11	0.03	80	..	...	...	140	220	...	...	...	Granulated blast furnace slag and hydrated lime
No. 4..	7.5	3	30	6	00	20.22	7.24	2.64	54.79	3.18	1.71	11.00	..	..	...	...	185	275	...	298	600	
No. 5..	12.0		30	9	00	19.46	4.92	1.98	37.44	27.65	0.42	5.44	50	..	...	...	...	...	...	312	654	(See Composition)
No. 6..	16.0	2	30	9	00	24.0	8.1		34.5	19.5	....	.....	65	..	...	...	100	...	...	225	350	Hydrated natural cement, wax distillate
No. 7..	4.0	2	00	4	30	30.86	11.11	2.67	47.79	2.01	1.96	3.14	64	..	106	223	328	414	738	1772	2842	Portland cement base
No. 8..	15.0		20	..	55	21.64	5.59	2.15	53.18	8.70	1.04	7.70	52 (loose)	60	90	...	...	...	...	225	...	Natural cement
No. 9..	5.0	1	00	..	..	24.76	9.34		35.77	21.65	1.50	6.40	65	..	...	75	...	...	413	564	1334	Not disclosed
No. 10..	2.0	4	30	12	00	12.96	4.68		74.24	7.84	0.33	....	54	..	...	...	25	65	...	122	...	Portland-cement clinker, blast-furnace slag, hydrated lime
No. 11..	12.5	3	00	6	00	.....	.....	....	.....	....	....	.....	75	..	98	150	190	225	298	390	508	
No. 12..	11.0	2	20	7	35	18.40	6.80		49.50	3.62	0.99	21.40	..	67 (gross)	...	...	120	170	...	804	1216	Portland cement base
No. 13..	14.2	6	00	..	..	12.68	2.85	1.98	54.94	15.88	1.03	10.86	75	..	...	...	165	258	...	1184	1880	60-per-cent portland cement, 40-per-cent hydrated lime
No. 14..	10.0	4	30	7	30	16.60	5.30	2.60	50.50	1.10	0.80	23.10	65	..	80	147	207	277	883	1008	1584	Portland cement, ground limestone, and aquagel.
No. 15..	10.0	4	30	7	30	13.56	4.42	1.84	60.60	4.27	0.84	14.26	57	..	...	35	70	...	150	250	...	Eminently hydraulic cement, lime and natural product
No. 16..	2.0	.	..	12	00	18.50	13.02		34.20	22.40	....	11.32	60	80	...	...	70	..	...	160	...	Not Disclosed
No. 17..	12.0	2	20	4	25	21.32	6.92	2.24	65.77	1.28	1.30	0.85	94.0	95.0	...	260	335	398	...	...	..	Not Disclosed

The tolerances being recommended in the proposed revisions are also matters that in many cases must be given further thought. The wording that would make the test methods more explicit would become too lengthy to be properly incorporated in such a document. Hence, it is particularly desirable that the Laboratory Manual which the committee issued a number of years ago be revised, with such modification of details as the inspectors of the Reference Laboratory have found desirable from their contacts with testing laboratories.

The Subcommittee on Strength has given further thought to the development of a new acceptance test for cements. It has continued its investigations of a plastic mortar compression specimen. The work that was reported last year indicated that the 2-in. mortar cube had many features to commend it, but at the same time the results among laboratories were not as concordant as those obtained in the use of briquets. Hence another series of tests was carried out by ten laboratories, using four different cements. In this series the making of the specimens was extended over five weeks, a complete set of tests being made by each laboratory each week. The scope of the tests, some of the data obtained, and some observations on the results are presented in the Appendix to this report.

It is the intention of the subcommittee to continue its investigations. This is very desirable, for although it is expected that the revised specifications for the purchase of cement, containing increased strength requirements, will be in effect before the end of the calendar year, there are many members of the committee, and non-members as well, who feel that a test based upon tensile strength is not as indicative of the value of a cement in concrete as a compression test. Although they bear in mind that essentially the committee is interested only in the development and promulgation of an acceptance test, many feel that even an acceptance test may possibly also be one that would be indicative of job requirements and service. Many data are being published which seem to show that high tensile strength is not indicative of high compressive strength in mortars or concretes, and therefore our tension tests are misleading. Some data are being published which seem to show that to predict durability, other than strength tests are needed. The committee as a whole is cognizant of these questionings and is giving them much thought and considerable research.

Subcommittee III on Fineness had its attention called to some apparent discrepancies in the fineness of some standard sand delivered to a laboratory. The subcommittee looked into the situation and as a result presented a report which is appended hereto. The committee decided it was not advisable at this time to make the changes in the standard suggested by the subcommittee in its report, but to bear it in mind in the case of future revisions, and in the meantime report the proposed revisions as information. The notes of the subcommittee should be of especial interest to all using fine sieves and should serve as a caution to those who are inclined to believe it is possible always to secure closely concordant values between laboratories or in the same laboratory when different sieves of the same mesh are used.

At the present time, the committee has under its jurisdiction standard specifications for two cements—portland and natural—and tentative specifications for high-early-strength portland cement. It is also very actively engaged in preparing tentative specifications for masonry cements. There has also been on the market for some time high-alumina cement, and it is understood there has just appeared on the domestic market the mixtures of portland cement and blast-furnace slag, so widely used in Europe, and for which there are nationally recognized specifications in England and Germany. It has also become evident that there are certain characteristics, such as peculiar consistency and sets, developing in the normal portland cements which have not been given the consideration that they should have been by the committee. These several facts all tending towards the need in some cases of diversified activities and in others of unified efforts, led the committee at its last meeting to authorize the chairman to appoint a special subcommittee to give careful consideration to the question of a reorganization of the committee. The problem before the subcommittee is essentially, "Could the committee function better if it were organized with subcommittees, each concerned with one of the types of cements, functioning possibly through special small groups appointed only for relatively short periods for studies of specific problems developing in the production and use of the particular cement, and in addition a rather small coordinating committee to direct and correlate the work of the several subcommittees?"

Again, it is necessary to ask that the Tentative Specifications and Tests for Compressive Strength of Portland Cement Mortars (C 9 - 16 T) be continued as tentative. The committee's continued work does not indicate that it can recommend anything better. Further, the methods prescribed in these tentative specifications for making and testing mortar cylinders are referred to and used to a degree that hardly justifies either their withdrawal or advancement to standard.

The election of officers resulted in the re-election of the present incumbents for the ensuing term of two years.

The recommendation appearing in this report has been submitted to letter ballot of the committee with the following results:

Item	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF EXISTING STANDARD Specifications and Tests for Portland Cement (C 9 – 26), immediate adoption..........	[a]	[a]	[a]

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[a] The revisions of the Standard Specifications and Tests for Portland Cement were balloted upon in itemized form according to the Section revised and of the 56 ballots returned the range of votes was 54 affirmative and none negative to 48 affirmative and 6 negative with 2 not voting.

This report has been submitted to letter ballot of the committee, which consists of 71 members; 57 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

P. H. BATES,
Chairman.

F. H. JACKSON,
Secretary.

EDITORIAL NOTE

The proposed immediate revision and rearrangement of the Standard Specifications and Tests for Portland Cement was approved at the annual meeting by a unanimous vote and subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications and methods of test in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 25 and 30, respectively.

REPORT OF SUBCOMMITTEE III ON FINENESS

As the result of tests conducted since the September, 1929, meeting of Committee C-1, the subcommittee recommends the following revision of the Standard Specifications and Tests for Portland Cement (C 9 – 26)[1] for publication as a tentative revision:[2]

Section 49.—Change to read as follows, by the addition of the italicized words and figures and the omission of those in brackets:

> 49. This sand shall be considered standard when not more than [5] *15* g. are retained on the No. 20 sieve and not more than 5 g. pass the No. 30 sieve, after [one minute] *5 minutes of* continuous sieving of a 100-g. sample, in the manner specified for sieving cement on the No. 200 sieve (see Section 31).

The tests referred to above were made on five different samples of standard sand, using four different certified sieves and four different methods of sieving. The residues in these tests varied from 1.7 per cent to 21.4 per cent. Large variations were found in the different samples of sand, in the different sieves, and in the different methods of sieving. Analysis of the results indicated that a difference of 0.01 mm. in the size of the sieve opening (or in diameter of sand grain) corresponds to a difference of about 5 per cent residue on the No. 20 sieve. Since the present tolerances for sieves permit a variation in sieve openings of 0.04 mm. on either side of the nominal opening, it is quite impossible to adhere to the tolerance of 5 per cent now specified without putting the burden entirely on the Ottawa Silica Co. This committee does not wish to put such a burden upon the Ottawa Silica Co., for it would obviously be most unfair to do so, and would very materially increase the price of the standard testing sand. Similarly, to reduce the tolerances on testing sieves would be unfair to the sieve manufacturers and raise the price of sieves.

That any of these changes would result in any practical improvement is doubtful, because a very limited series of comparative tests made on briquets, using in the one case Ottawa sand, No. 20 to No. 25 sieve range, and in the other sand, No. 25 to No. 30 sieve range, gave no appreciable differences in strength at 7 days.

The subcommittee therefore recommends the above revision for publication as a tentative revision of the Standard Specifications C 9 – 26.[2]

Respectfully submitted on behalf of the subcommittee,

J. C. PEARSON,
Chairman.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 23.

[2] Recommended by Committee C-1 for publication as information only.—ED.

REPORT OF SUBCOMMITTEE XIV ON CEMENT REFERENCE LABORATORY

Preparatory Work:

The activities of the Cement Reference Laboratory for the first few months were devoted to preparations for carrying out the work, securing and training personnel, purchasing and calibrating field equipment, and outlining the procedure to be followed. Many unforeseen questions arose during the progress of this preliminary work, and the laboratory is learning more every day about the details affecting cement testing. The best source of such learning has been the actual performance of the inspection work. The methods of procedure have been modified from time to time, although from the beginning the effort has been to achieve the real purpose of the laboratory, that is, the promotion of improvement and uniformity in cement testing. During the preparatory work, and throughout the subsequent activities, the laboratory has been generously assisted by the members of the various laboratories of the National Bureau of Standards, and their advice on apparatus and the tests thereof have been very valuable.

Field Inspection:

The major portion of the laboratory's efforts has been devoted to the field inspection of laboratories and the cement-testing equipment and methods used therein, since it appeared that the other work which had been planned would be better carried out after these inspections had been made. There had been received, up to April 17, 1930, 177 requests for inspections of laboratories and inspections had been completed at 125 laboratories. Table I shows the classification and geographical distribution of these laboratories. The kind and quantity of equipment tested and approved during the inspections of 119 laboratories are briefly outlined in Table II.

The field inspection up to the date mentioned has included work in 36 states. The eastern, southern and southwestern states have been covered, as well as part of California, and considerable of the central and Great Lakes regions. A few requests have been received from territories which have already been visited. The inspection is being continued, three men now (April, 1930) being in the field, one in California, one in the Great Lakes section, while the third is in the

TABLE I.—LOCATION AND CLASSIFICATION OF CEMENT-TESTING LABORATORIES REQUESTING INSPECTION

(Up to April 17, 1930)

STATE	PRODUCERS	COMMERCIAL	UNIVERSITIES AND STATE HIGHWAYS	MUNICIPAL	MISCELLANEOUS	TOTAL
Alabama	3	1	..	..	..	4
Arkansas	..	..	1	..	..	1
California	7	3	..	3	1	14
Colorado	..	..	2	..	1	3
Connecticut	..	1	..	..	..	1
District of Columbia	..	..	..	..	1	1
Florida	1	..	1	..	..	2
Georgia	1	1	1	..	..	3
Illinois	3	3	1	..	..	7
Indiana	4	..	1	..	..	5
Iowa	2	1	..	..	..	3
Kansas	3	..	1	..	..	4
Kentucky	..	..	..	1	..	1
Maine	1	..	1	..	..	2
Maryland	1	1	..	..	..	2
Massachusetts	..	2	2	..	..	4
Michigan	5	4	2	..	..	11
Minnesota	1	..	3	..	..	4
Missouri	2	..	2	..	..	4
Nevada	..	..	1	..	..	1
New Hampshire	..	1	1	..	..	2
New Jersey	2	..	2	1	..	5
New Mexico	..	..	2	..	..	2
New York	6	2	1	1	..	10
Ohio	6	7	2	..	..	15
Oklahoma	..	1	1	..	..	2
Oregon	2	..	1	..	..	3
Pennsylvania	16	5	3	..	1	25
Rhode Island	..	..	2	..	..	2
South Dakota	..	..	2	..	..	2
Tennessee	4	..	1	..	1	6
Texas	6	7	2	..	..	15
Virginia	..	1	..	..	..	1
Washington	3	1	2	..	..	6
West Virginia	2	..	..	..	..	2
Wisconsin	1	..	1	..	..	2
Total requests	82	42	42	6	5	177
Inspections completed up to April 17, 1930	61	35	23	3	3	125

central states. By the end of June, 1930, inspections will have been made at about 150 laboratories. The earlier inspections were made in districts where the travel between closely adjacent laboratories required but little time. The men are now operating in localities where more time is consumed in moving their equipment between laboratories, and in addition, some of the work has been amplified so that hereafter the rate of inspection will probably be less than formerly.

TABLE II.—APPARATUS INSPECTED IN THE FIELD DURING INSPECTION OF 119 CEMENT-TESTING LABORATORIES.

	INSPECTED	APPROVED
Moist cabinets	118	13[a]
Steam chests	117	57[b]
Balances for fineness	120	37
Balances for mixes	141	110
Weights for fineness, pieces	803	772[b]
Weights for mixes, pieces	1537	1485[b]
Graduates	299	261
Vicat apparatus	141	42[b]
Gillmore needles, pairs	147	99[b,c]
Briquet molds	4578	3155[b]
Tension testing machines	127	50[d]
Total	8128	6081

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[a] Includes only apparatus with automatic temperature controls.

[b] Includes apparatus satisfactorily adjusted during inspection.

[c] Since January 1, 1930, tapered shank needles have not been approved on basis of micrometer measurements.

[d] Some machines were approved when grips were not in strict accordance with specifications, but were of type and dimensions calculated to secure the intent of the specifications.

The field inspection of a laboratory, in general, consists of four parts: (1) the inspection of apparatus and conditions; (2) the demonstration of test methods and discussion of points of interest arising therein; (3) the confirmatory report issued by this laboratory; and (4) the acknowledgment of the report with the occasional discussion of the points of interest involved. The report (one copy only) is issued to the party who requested the inspection and is confidential. It should be remembered that in many cases the inspector visits a laboratory not at the request of the local chemist or director, but at the request of some supervising official at another location. However, the field contacts in general have been pleasing and the laboratories have cooperated quite satisfactorily.

It is true that some laboratories were only slightly interested in the work, and that other laboratories showed evidence of but little cement testing being done in them. However, in the first case, it is thought that, at least in some instances, more interest will be shown hereafter. In the second case, it seems that the work may be particularly valuable with respect to future testing, since the small amount of cement testing recently performed may not have aroused much interest in keeping apparatus and methods in accordance with specifications.

At this point it is desired to invite attention to the fact that in some laboratories, where methods and apparatus may otherwise be relatively good, there is the disposition to consider some part of the specifications and methods of testing as not satisfactory, at least in wording, and to make some departures from the requirements specified, with the idea of improving on the specifications or methods, or perhaps, better securing the real intent of the specifications. Such deviations from the standards specified may account for some of the disagreement in test results, and they perhaps hinder the concentration of attention on points in specifications which merit study.

In general, it seems that the field inspections have been very profitable. Certainly, the laboratory staff has learned much from them. Also, the tabulation of the many items of information collected by the inspectors is providing much material for consideration later by interested parties and committees. Statistics are being assembled on several hundred questions involving apparatus and methods. Only a casual inspection is needed to convince one that not all of the differences in results of cement tests are due to the "personal equation." In a number of laboratories, where the equipment and the conditions indicated a very limited amount of cement testing being performed, the methods demonstrated were more closely in accordance with specification requirements than at some of the larger and better equipped laboratories.

Occasional advice from the inspectors, notations in their report forms, and correspondence with laboratories, indicate that some differences in methods have been eliminated by the comparisons and discussions between the laboratories and the inspectors. Also, it is known that considerable apparatus has been adjusted or replaced in order to comply with specifications. Some of the adjustments have been made by the inspectors during the progress of their work. Demonstrations have been made before gatherings of highway laboratory staffs and engineering classes in the universities. The inspectors have made every effort to have their work appear as part of a cooperative endeavor to improve cement testing and collect information of value, and not appear as of an unduly critical nature. Many of the laboratories have expressed great interest in the time of the next inspection.

Apparatus Tested at the Bureau of Standards:

Only a few pieces of apparatus have been submitted to the Reference Laboratory for test at the National Bureau of Standards. However, inquiries have been received from a number of manufacturers and dealers interested in having apparatus certified. Fees are charged for apparatus tested at the Bureau, the fees being payable to the Bureau of Standards. The fees already set for test of some of the apparatus have been made in general accordance with related work of the Bureau laboratories.

Purchasers and manufacturers are being advised, in correspondence relating to the tests of apparatus, that certification by the Reference Laboratory is not necessary, and that the purchaser can readily check up most of the apparatus for himself, provided he has suitable weights, micrometers, and simple apparatus for measurements. It is not the intention to discourage tests at the Bureau, but to encourage the purchaser and user to check their apparatus, which apparently has not been done in many instances. A number of laboratories have demonstrated that the tolerances on apparatus can be readily applied by themselves in checking and adjusting their equipment.

Manual of Cement Testing:

Reports from a number of sources indicate that the present A.S.T.M. Manual of Cement Testing[1] has been a valuable publication, even though it is brief and is in need of some revision. A new publication, larger and more detailed than the present manual, has appeared to be a worth-while project and material for it is being collected. The idea of compiling such a book was entertained some years before the actual establishment of the laboratory, and now the questions and suggestions which have accumulated during the past year, in addition to the items of interest in the inspectors' field reports, are of great assistance in suggesting material. There seems to be need, particularly, for discussion of the subject of apparatus. The Reference Laboratory's experience in considering tolerances, the purchase of testing equipment and in answering general questions, as well as in the field inspection work, has made it evident that a more satisfactory condition might be brought about if the purchasers and users of cement testing apparatus had more definite ideas of what should be required of the apparatus, how it should be tested and used, and what should be regarded as its limitations. The important thing is that the book itself must contain the data to be conveyed to the laboratory operator, and not merely refer to lengthy publications which may not be accessible to the operator for whom the book is intended. Suggestions as to matter for inclusion in this publication are invited.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 161 (1925).

Bibliography:

Along with the preparation of the manual it is planned to prepare a bibliography referring particularly to cement testing methods and apparatus. The present manual already contains many references. Occasional inquiries have demonstrated the desirability of such compilation. It is not intended that the bibliography shall present briefs of results and conclusions, but the abstracts should be sufficient to convey an idea of the scope and purpose of each reference. Some material is being gathered for this purpose.

Instruction of Cement Testers at the Bureau of Standards:

Only a few requests have been received for instruction to be given to operators sent to the Bureau of Standards. No attempt has been made to carry out this part of the work as yet, and proper publicity will be given when the time arrives to begin these courses. A brief outline of the proposed course has been prepared, and includes the following general items:

Demonstration of testing methods by the Reference Laboratory and practice by the student;

Discussion of the standard specifications and test, the manual of cement testing and related matter;

Demonstration and instruction in the use, care and testing of apparatus;

Discussion of the effects of variables in cement laboratory work;

Brief survey of related work in the laboratories of the Bureau of Standards;

Furnishing literature or references to literature dealing with cement testing.

The endeavor will be to make the course of more interest than would be secured from only the comparison of methods of making the tests required by the specifications. The proposed course when amplified will cover a definite time, throughout which time the student must attend and during which a member of the Reference Laboratory will devote his time to the instruction.

Comparative Tests:

Comparative tests have not yet been undertaken, since it was decided that the most value would be derived therefrom if they were entered upon after many of the cooperating laboratories had been inspected and had been given the opportunity of discussing test methods with the inspectors. Apparently, the Reference Laboratory can expect an ample number of laboratories to cooperate in this work. The air conditioning apparatus in the Reference Laboratory insures uniform conditions of temperature and humidity under which this laboratory's part of the comparative test program can be performed.

Tolerances:

Careful consideration should be given to the proposed tolerances and the requirements affecting apparatus of the Standard Specifications and Tests for Portland Cement (C 9 - 26)[1] before changes are made therein. Details of condition of apparatus already examined, as well as many comments on the points involved, have provided considerable material on this subject. The following brief comments on tolerances are offered as matters of general information, and not as recommendations or criticisms:

Vicat Apparatus.—The weight requirements are easily met. The tolerances on diameters are quite close, but they too can be complied with. A slight change in tolerances might permit the use of stock drill rod for needles. The tolerance on height of mold is quite close, but is generally complied with and really offers no problem. However, attention is invited to one point regarding which there is no specified tolerance, but which can be readily covered by inspection. It has been found necessary to inspect the graduated scales on this apparatus. No tolerances are proposed, since the scale should certainly bear visual comparison with a satisfactory steel scale, and a tolerance of 0.2 mm. in the usual 50 or 60-mm. length should be sufficient. The point of interest is that these scales are not always correct, some of them being in error in their over-all length, while again errors have been observed at intermediate points. In one case the deficiency in length amounted to about 3 mm., which would be appreciable in tests of needle penetrations.

Gillmore Needles.—Tolerances on weights appear satisfactory and are easily complied with. Most of the needles examined have had diameters less than the permissible diameter, some of them having end areas of only about one-third of the specified amount. It has been found impracticable to use micrometers to measure with appropriate accuracy the ends of some of the tapered shank needles. However, many of the laboratories are accepting the inspectors' recommendations that they refinish the needles with a short length of straight barrel at the end, about $\frac{3}{16}$ in. long, and of the proper diameter. This permits the ready use of a micrometer and also permits the end to be polished or ground off when needed without such rapid loss of diameter as is the case with the tapered shank needles. The Reference Laboratory has also fitted some needles with replaceable needles. The present diameters are in fractions of an inch. A slight change in diameters, or in tolerances, might permit the use of drill rod stock if replaceable ends were desired.

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[1] See p. 417; also 1927 Book of A.S.T.M. Standards, Part II, p. 23.

Balances and Weights for Fineness Tests and Weighing Mixes.—The tolerances on both balances and weights appear reasonable and satisfactory, although some additional points should be covered by specifications, such as appropriate requirements for behavior under eccentric loading on pan balances, and the like, which points are covered by the inspectors' procedure.

Glass Graduates.—The tolerances do not appear severe. Additional tolerances would seem appropriate for graduates outside of the range 100 to 200 ml., particularly on the smaller graduates, and the inspectors have some appropriate instructions on this point. Full lines should be insisted upon when buying graduates, for the very short type of graduation does not permit ready or accurate readings.

Briquet Molds.—The requirements for width at waist seem very satisfactory, many old molds even meet the more exacting requirements specified for new molds. The tolerance on thickness has received considerable discussion. It might be mentioned that some molds which have been in use for a long time comply with specifications on this point, while some recently purchased fail to meet the requirements.

Tension Testing Machines.—The tolerance on accuracy of load indications seems reasonable, and is the same as the A.S.T.M. requirements for testing machines.[1] There should be inserted some additional tolerances governing grips. The inspectors require that the rollers shall be in diameter 0.50 in. ± 0.01 in., that they be parallel within 0.02 in., and that the space between the faces of the rollers shall be 1.25 in. ± 0.02 in. These requirements should not be difficult to meet, but there are some grips which are quite different from the requirements of the present specifications with respect to spread and dimensions of rollers. Additional data on sensitivity of the machines have been collected in some instances, although this does not enter into the specification requirements as revised by the proposed tolerances. Attention is invited to the fact that the dials of some of the spring-scale weighing devices cannot be read very closely and that the weight indications of these spring scales at various loads are not always in agreement with what might be expected. It is suggested that machines with spring-scale weighing devices should also be provided with a graduated beam and suitably arranged weights so that the indications of the spring scale could be checked or replaced by probably more accurate weighings on the beam system when so desired.

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[1] Standard Methods of Verification of Testing Machines (A.S.T.M. Designation: E 4) of the American Society for Testing Materials, 1927 Book of A.S.T.M. Standards, Part II, p. 921.

General.—In general, the tolerances have not appeared unreasonable. Indeed, there have been comments to the effect that the requirements are not stringent enough. However, it is probable that some revisions or additions to the tolerances will be found desirable as work progresses, and the comments and suggestions that have been accumulated will assist in such considerations. Attention is invited to the fact that some of the proposed tolerances are less severe than the portions of the standard specifications which they are intended to replace.

Test Methods and Apparatus:

In addition to the proposed comparative tests, there are a number of methods and variables which should be studied. With the completion of the greater part of the first season of field work attention can be given to some of these problems. The personnel will then have had the benefit of the observations they have made during the past months. Study has already been given to some of these questions. Some equipment manufacturers have shown interest in developing apparatus better fitted to meet the requirements of the cement testing laboratory and, although some of the developments have been largely in the nature of modification or slight improvement in the usual types of apparatus, yet it is hoped that further interest will be manifest in this matter.

Calibration of Compression Testing Machines:

Some laboratories have expressed keen interest in the matter of calibration of their compression testing machines. Of course, such work is not now included in the duties of the inspectors, and some of the machines involved were of sizes larger than ordinarily required for compression tests of mortar specimens. However, attention is invited to the fact that if the compression mortar test were to be made standard, or as a tentative standard be made by many laboratories, there would arise the question of calibration of compression machines. This would involve the selection and purchase of suitable calibrating apparatus and in addition would add greatly to the time spent by an inspector at a laboratory. Attention should be given to the size and nature of machines used for these compressive mortar tests, for it is very inadvisable to test small mortar specimens on machines of such capacity that the indicated load is only 1 or 2 per cent of the capacity.

General Information:

From the inspection reports, general correspondence and from conversations there have been accumulated numerous items of interest in connection with specifications, apparatus and general laboratory procedure. Particularly interesting have been some of the comments on specification methods. These numerous items are collected into a card index for use in subsequent and more detailed reports to the various interested committees. Perhaps many of these items are not new but the present work tends to collect them at one common point for study. It is hoped that such laboratories or operators as may have in mind questions about insufficiently explained portions of the specifications, or any apparent inconsistencies therein, or even matters which deserve particular study with the view to improving the methods, will promptly forward to the Reference Laboratory their comments or suggestions.

Results of Work to Date:

Briefly stated, the principal results of the work to date might be listed as follows:

1. Acquisition of an experienced personnel;

2. Data on apparatus, test methods and conditions in many laboratories;

3. Numerous reports of laboratory inspections issued to interested parties and the comments received in reply;

4. Elimination of some variations in test methods;

5. Improvement of condition of numerous pieces of apparatus in laboratories;

6. Demonstrations have made some operators more familiar with standard methods as interpreted by the Reference Laboratory;

7. Interest shown by instrument manufacturers and dealers in requirements for testing apparatus;

8. Accumulation of many items of information for compilation and study.

Respectfully submitted on behalf of the subcommittee,

F. W. KELLEY,
Chairman.

APPENDIX

COOPERATIVE TESTS OF CEMENTS

INTRODUCTION

Data appearing in a paper by E. M. Brickett presented before the society in 1928[1] representing results secured with a plastic mortar compression test for cement appeared so promising that Subcommittee VII on Strength, of Committee C-1, outlined a series of tests to compare this method with the standard briquet test.[2] A report on this series submitted to Committee C-1 in June, 1929, gave complete data and discussed some of the more significant features of the tests.

The briquet and cube tests by the seven laboratories in the June, 1929, report showed better concordance than in the previous tests by 47 laboratories reported to the Society in 1928.[3] The results of the briquet tests were somewhat more concordant than the cube tests. However, it was believed that when laboratories became more familiar with the plastic mortar cube test, as concordant results would be obtained with it as with the present standard sand briquet. In general, the plastic mortar compression test appeared to offer a better criterion of concrete strength than the briquet.

Subcommittee VII at a meeting in New York City on May 23, 1929, outlined further studies for the purpose of investigating variations, in tests of 1:3 standard sand briquets and plastic mortar cubes made over a period of 5 consecutive weeks, both within a given laboratory and between various laboratories. It was believed that these additional tests would afford the cooperating laboratories an opportunity to obtain further practice in making and testing plastic mortar cubes. This report gives the results of these later studies which were made on four portland cements by ten laboratories in cooperation with the subcommittee.

SCOPE OF TESTS

The program of tests and details of the methods pursued were as follows: Each cooperating laboratory made 1:3 standard sand briquets and 2-in. cubes of run-of-mine Ottawa sand mortar with each of four portland cements. A constant amount of mixing water (10.4 per cent by weight of dry materials) was used in all cases in mixing the 1:3 standard sand mortars. The mortar used in the cube tests was mixed to a constant water-cement ratio of 0.80. The mix was 1:2.75 by weight and the consistency was such that the mortar could be puddled in the molds with the fingers. The flow varied with each cement, the average flow ranging from 138 for cement B to 158 for cement D.

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[1] E. M. Brickett, "A Plastic Mortar Compression Test for Cement," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 432 (1928).

[2] Tentative Outline of Test Procedure for Cooperative Plastic Mortar Tests, Report of Committee C-1 on Cement, Appendix II, *Proceedings*, Am. Soc. Testing Mats., Vol 29, Part I, p. 266 (1929).

[3] **Report of Subcommittee VII, *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 261 (1928).**

Each cooperating laboratory made a group of specimens of each of four cements, cements A, B, C and D, purchased in the open market, for test at ages of 1, 3, 7 and 28 days. This group was repeated five times in consecutive weeks, three specimens being made each week for each age and condition of test.

OUTLINE OF TESTS

The outline of tests is as follows:

Type of Specimen	Mix by Weight of Dry Material	Sand	Water	Age at Test	Strength Tests	
					On Each Cement	On 4 Cements
Standard Briquets	1:3	Standard Ottawa ...	10.4 per cent by weight of dry material.......	1 day 3 days 7 days 28 days	12	48
2-in Cubes.........	1:2.75	Run-of-Mine Ottawa	0.80 water-cement ratio...	1 day 3 days 7 days 28 days	12	48
Total per week........						96
Total for five weeks........						480

Tension Tests of 1:3 Standard Sand Briquets:

The specimens were made in accordance with the Society's Standard Specifications and Tests for Portland Cement (C 9 – 26) and the Manual of Cement Testing, except that a uniform water content of 10.4 per cent by weight of dry material was used.

Compression Tests of 2-in. Plastic Mortar Cubes:

The specimens were made with run-of-mine Ottawa sand, mix 1:2.75 by weight, water-cement ratio 0.80 for all cements. The cement and sand were mixed dry and then placed in a shallow metal pan which was previously wiped with a damp cloth, care being taken to have the pan at the same degree of wetness for each batch. The measured quantity of water was then poured in a crater formed in the cement and sand. One minute was allowed for absorption of water by the dry material, meanwhile turning the material into the crater with a trowel. Mixing and kneading with the gloved hands was then begun and continued vigorously for 1½ minutes. Thirty seconds was then allowed to fill the flow mold of a 10-in. flow table. The flow table was then given thirty ⅛-in. drops in 30 seconds and the flow measured in millimeters. The surface of the flow table was wiped with waste or cloth dampened in kerosine. After the flow test, the mortar was returned to the pan and remixed for 10 to 15 seconds, the molds filled in two layers and each layer lightly puddled with the

TABLE I.—SUMMARY OF TENSILE STRENGTHS OF 1 : 3 STANDARD SAND BRIQUETS.

Strengths are based on the averages of three specimens made on the same day.

Laboratory	Tensile Strength Over 5-Week Period, lb. per sq. in.																			
	Cement A					Cement B					Cement C					Cement D				
	Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference	
				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average
										1-DAY TESTS										
No. 1	100	110	85	25	25.0	85	95	75	20	23.5	70	75	65	10	14.3	235	245	230	15	6.4
No. 2	120	125	110	15	12.5	95	105	80	25	26.3	75	80	70	10	13.3	295	305	280	25	8.5
No. 3	120	130	105	25	20.8	105	115	80	35	33.3	85	100	75	25	29.4	300	325	275	50	16.6
No. 4	100	115	80	35	35.0	70	85	45	40	57.2	55	65	40	25	45.5	240	255	220	35	14.6
No. 5[a]	110	120	100	20	18.2	90	100	65	35	38.9	55	60	50	10	18.2	270	285	265	20	7.4
No. 6	100	115	80	35	35.0	85	115	65	50	58.8	80	95	60	35	43.8	270	295	230	65	24.1
No. 7	120	130	110	20	16.7	90	100	80	20	22.3	65	85	55	30	46.2	280	305	250	55	19.6
No. 8	80	110	40	70	87.5	70	95	45	50	71.4	50	60	40	20	40.0	230	275	175	100	43.5
No. 9	130	135	130	5	3.8	125	140	105	35	28.0	95	115	80	35	36.8	295	305	280	25	8.5
No. 10	110	120	100	20	18 2	90	110	60	50	55.5	75	80	55	25	33.3	270	295	250	45	16.7
Average	110	...	..	27	25 0	90	...	...	36	41.5	70	...	...	22	32.1	270	...	...	44	16.6
High	130	...	...	..	....	125	...	...	..	....	95	...	...	..	....	300	...	...	..	....
Low	80	...	...	..	....	70	...	...	..	....	50	...	...	..	....	230	...	...	..	....
Difference	50	...	...	..	....	55	...	...	..	....	45	...	...	..	....	70	...	...	..	....
Per Cent of Average	45.5	...	...	..	....	61.1	...	...	..	....	64.3	...	...	..	....	25.9	...	...	..	....
										3-DAY TESTS										
No. 1	195	205	175	30	15.4	180	190	165	25	13.9	160	180	145	35	21.9	345	365	310	55	16.0
No. 2	215	235	200	35	16.3	210	215	195	20	9.5	175	190	165	25	14.3	410	435	395	40	9.8
No. 3	210	215	205	10	4.8	205	210	195	15	7.3	180	200	175	25	13.9	390	400	380	20	5.1
No. 4	185	205	165	40	21.6	185	210	155	55	29.7	150	175	140	35	23.3	395	425	360	65	16.4
No. 5	215	240	200	40	18.6	210	225	185	40	19.0	165	180	155	25	15.2	410	420	400	20	4.9
No. 6	195	205	175	30	15.4	210	220	195	25	11.9	165	185	145	40	24.2	360	370	355	15	4.2
No. 7	230	245	220	25	10.9	235	255	215	40	17.0	190	220	165	55	28.9	445	465	415	50	11.2
No. 8	200	235	170	65	32.5	200	210	180	30	15.0	170	200	150	50	29.4	360	385	335	50	13.9
No. 9	225	235	215	20	8.9	220	235	195	40	18.2	175	195	165	30	17.1	400	415	385	30	7.5
No. 10	215	235	200	35	16.3	200	215	185	30	15.0	165	180	155	25	15.2	405	420	385	35	8.6
Average	210	...	...	33	16.1	205	...	...	32	15.6	170	...	...	35	20.3	390	...	...	38	9.8
High	230	...	...	..	....	235	...	...	..	....	190	...	...	..	....	445	...	...	..	....
Low	185	...	...	..	....	180	...	...	..	....	150	...	...	..	....	345	...	...	..	....
Difference	45	...	...	..	....	55	...	...	..	....	40	...	...	..	....	100	...	...	..	....
Per Cent of Average	21.4	...	...	..	....	26.8	...	...	..	....	23.6	...	...	..	....	25.6	...	...	..	....

[a] Average of four weekly tests.

TABLE I.—*Continued.*

Laboratory	Tensile Strengths Over 5-Week Period, lb. per sq. in.																			
	Cement A					Cement B					Cement C					Cement D				
	Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference	
				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average
7-DAY TESTS																				
No. 1	250	260	235	25	10.0	245	255	220	35	14.3	235	245	225	20	8.5	395	410	385	25	6.3
No. 2	290	305	285	20	6.9	285	285	280	5	1.8	275	285	255	30	10.9	485	510	465	45	9.3
No. 3	270	295	245	50	18.5	285	310	265	45	15.8	270	290	255	35	13.0	445	470	395	75	16.8
No. 4	280	305	265	40	14.3	280	315	245	70	25.0	245	255	225	30	12.3	465	490	430	60	12.9
No. 5	280	285	270	15	5.4	280	305	270	35	12.5	250	270	230	40	16.0	450	475	415	60	13.3
No. 6	275	295	255	40	14.6	270	285	265	20	7.4	265	325	230	95	35.9	455	470	425	45	9.9
No. 7	310	330	290	40	12.9	315	355	290	65	20.6	295	325	260	65	22.1	490	535	450	85	17.4
No. 8	275	295	260	35	12.7	265	285	255	30	11.3	260	285	240	45	17.3	425	450	385	65	15.3
No. 9	285	310	255	55	19.3	285	305	245	60	21.0	270	305	240	65	24.1	470	475	460	15	3.2
No. 10	285	300	270	30	10.5	270	290	245	45	16.7	250	265	230	35	14.0	485	495	470	25	5.1
Average	280	...	...	35	12.5	280	...	...	41	14.6	260	...	...	46	17.4	455	...	...	50	10.9
High	310	...	...	..	....	315	...	...	..	....	295	...	...	..	....	490	...	...	..	....
Low	250	...	...	..	....	245	...	...	..	....	235	...	...	..	....	395	...	...	..	....
Difference	60	...	...	..	....	70	...	...	..	....	60	...	...	..	....	95	...	...	..	....
Per Cent of Average	21.4	...	...	..	....	25.0	...	...	..	....	23.1	...	...	..	....	20.8	...	...	..	....
28-DAY TESTS																				
No. 1	370	395	345	50	13.5	355	375	330	45	12.7	360	385	335	50	13.9	435	455	425	30	6.9
No. 2	400	415	395	20	5.0	400	415	385	30	7.5	415	420	390	30	7.2	510	550	495	55	10.8
No. 3	375	385	365	20	5.3	380	400	365	35	9.2	385	390	365	25	6.5	460	485	430	55	12.0
No. 4	370	390	345	45	12.2	385	415	370	45	11.7	380	410	345	65	17.1	495	560	470	90	18.2
No. 5	370	405	340	65	17.6	405	420	395	25	6.2	385	395	370	25	6.5	490	535	460	75	15.3
No. 6	365	385	325	60	16.5	375	400	335	65	17.3	365	380	345	35	9.6	475	510	435	75	15.8
No. 7	410	420	390	30	7.3	430	450	395	55	12.8	440	455	425	30	6.8	535	555	515	40	7.5
No. 8	365	400	335	65	17.8	375	385	370	15	4.0	390	415	370	45	11.5	470	505	435	70	14.9
No. 9	380	400	360	40	10.5	380	410	360	50	13.3	390	400	380	20	5.1	490	510	475	35	7.2
No. 10	405	435	385	50	12.3	390	415	360	55	14.1	400	415	385	30	7.5	510	535	495	40	7.8
Average	380	...	...	45	11.8	385	...	...	42	10.9	390	...	...	35	9.2	485	...	...	56	11.6
High	410	...	...	..	....	430	...	...	..	....	440	...	...	..	....	535	...	...	..	....
Low	365	...	...	..	....	355	...	...	..	....	360	...	...	..	....	435	...	...	..	....
Difference	45	...	...	..	....	75	...	...	..	....	80	...	...	..	....	100	...	...	..	....
Per Cent of Average	11.8	...	...	..	....	19.5	...	...	..	....	20.5	...	...	..	....	18.7	...	...	..	....

fingers. Specimens were kept under wet burlap for 4 hours, then struck off and stored in the moist room at 70° F. The molds were removed after 20 to 24 hours and the specimens cured in water at 70° F. until test, then tested damp. The cubes were tested on the side perpendicular to direction of molding.

DISCUSSION OF TESTS

Tables I and II give the average tensile and compressive strengths obtained by each laboratory with each cement at each age over the 5-week period. Included in these two tables are the high and low strengths and the spreads between them both in pounds per square inch and as a percentage of the average strength.

There are inconsistencies in these results which are not explainable from the data submitted. For example, laboratory No. 1 generally obtained low briquet strengths and high cube strengths at early ages while laboratory No. 8 obtained low briquet strengths and about average cube strengths at 1 day but high cube strengths at later ages.

TABLE II.—SUMMARY OF COMPRESSIVE STRENGTHS OF 2-IN. PLASTIC MORTAR CUBES.

Strengths are based on the averages of three specimens made on the same day.

Laboratory	Compressive Strengths of 2-in. Cubes Over 5-Week Period, lb. per sq. in.																			
	Cement A					Cement B					Cement C					Cement D				
	Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference	
				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average
1-DAY TESTS																				
No. 1	580	620	560	60	10.3	520	540	460	80	15.4	280	280	270	10	3.6	1870	1940	1810	130	7.0
No. 2	440	460	430	130	6.8	330	390	310	80	24.2	210	240	190	50	23.8	1520	1760	1440	320	21.1
No. 3	460	530	420	110	23.9	380	450	310	140	36.8	210	250	120	130	61.9	1540	1660	1440	220	14.3
No. 4	370	410	260	150	40.5	270	320	210	110	40.7	190	210	150	60	31.6	1180	1290	1020	270	22.9
No. 5	510	600	460	140	27.5	350	450	300	150	42.9	220	240	195	45	20.4	1460	1610	1320	290	19.8
No. 6	390	480	300	180	46.2	310	380	240	140	45.3	230	270	190	80	34.8	1350	1580	1120	460	34.0
No. 7	380	400	370	30	7.9	310	320	280	40	12.9	190	200	190	10	5.3	1240	1300	1150	150	12.1
No. 8	390	460	300	160	41.1	340	530	250	280	82.4	200	250	130	120	60.0	1380	1640	910	730	52.8
No. 9	450	500	320	180	40.0	370	480	230	250	67.6	220	290	150	140	63.6	1630	1900	1460	440	27.0
No. 10	450	580	360	220	49.0	350	460	280	180	51.4	220	280	180	100	45.4	1520	1770	1180	590	38.8
Average	440	...	...	126	29.3	360	...	...	145	42.0	220	...	...	74	35.0	1470	....	....	360	25.0
High	580	...	...	...	....	520	...	...	...	....	280	...	...	...	....	1870	....	....	...	....
Low	370	...	...	...	....	270	...	...	...	....	190	...	...	...	....	1180	....	....	...	....
Difference	210	...	...	...	....	250	...	...	...	....	90	...	...	...	....	690	....	....	...	....
Per Cent of Average	47.8	...	...	...	....	69.4	...	...	...	....	40.9	...	...	...	....	46.9	....	....	...	....
3-DAY TESTS																				
No. 1	1270	1570	1170	400	31.5	1160	1220	1110	110	9.5	820	870	790	80	9.8	4400	4700	4040	660	15.0
No. 2	1120	1170	1070	100	8.9	1080	1130	1020	110	10.2	800	830	750	80	10.0	4260	4350	4090	260	6.1
No. 3	1030	1200	940	260	25.2	950	1000	920	80	8.4	740	820	690	130	17.6	3830	4030	3510	520	13.6
No. 4	1010	1100	880	220	21.8	1010	1080	930	150	14.8	820	900	740	160	19.6	3830	4350	3570	780	20.4
No. 5	1320	1410	1220	190	14.4	1150	1200	1090	110	9.6	870	950	800	150	17.3	3910	4040	3840	200	5.1
No. 6	970	1060	860	200	20.6	950	1140	800	340	35.8	780	890	640	250	32.1	3530	3830	3200	630	17.8
No. 7	1010	1050	990	60	5.9	970	1060	920	140	14.4	780	800	740	60	7.7	3920	4140	3780	360	9.2
No. 8	1290	1720	1080	640	49.6	1400	1710	990	720	51.4	980	1200	760	440	45.0	4060	4430	3480	950	23.4
No. 9	1030	1120	860	260	25.2	970	990	910	80	8.3	690	810	590	220	32.0	3730	3880	3540	340	9.1
No. 10	1170	1420	1060	360	30.8	1100	1240	970	270	24.5	850	990	780	210	24.7	4160	4450	3910	540	13.0
Average	1120	....	....	269	23.4	1070	....	....	211	18.7	810	....	....	178	21.6	3960	....	....	524	13.3
High	1320	....	....	...	....	1400	....	....	...	....	980	....	....	...	....	4400	....	....	...	....
Low	970	....	....	...	....	950	....	....	...	....	690	....	....	...	....	3530	....	....	...	....
Difference	350	....	....	...	....	450	....	....	...	....	290	....	....	...	....	870	....	....	...	....
Per Cent of Average	31.2	....	....	...	....	42.0	....	....	...	....	35.8	....	....	...	....	22.0	....	....	...	....

TABLE II.—*Continued.*

Laboratory	Compressive Strengths of 2-in. Cubes Over 5-Week Period, lb. per sq. in.																			
	Cement A					Cement B					Cement C					Cement D				
	Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference		Average	High	Low	Difference	
				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average				Pounds	Per Cent of Average
7-DAY TESTS																				
No. 1	1760	1790	1710	80	4.6	1750	1870	1620	250	14.3	1440	1610	1300	310	21.6	5470	5920	5250	670	12.2
No. 2	1780	1830	1700	130	7.3	1710	1780	1630	150	8.8	1550	1630	1460	170	11.0	6040	6240	5930	310	5.1
No. 3	1460	1710	1260	450	30.8	1410	1510	1230	280	12.8	1350	1450	1200	250	18.5	5340	5720	4840	880	16.5
No. 4	1650	1840	1520	320	19.4	1720	1900	1650	250	14.6	1600	1680	1450	230	14.4	5440	5970	4780	1190	21.9
No. 5	1920	2050	1580	470	24.5	1870	2050	1700	350	18.7	1730	1940	1580	360	20.8	5820	5960	5720	240	4.1
No. 6	1550	1710	1460	250	16.1	1560	1610	1480	130	8.3	1330	1490	1060	430	32.3	5200	5590	4750	840	16.2
No. 7	1600	1750	1510	240	15.0	1690	1890	1510	380	22.5	1480	1530	1450	80	5.4	5670	6010	5310	700	12.3
No. 8	2130	2420	1820	600	28.1	2160	2330	1860	470	21.7	1860	1930	1760	170	9.1	5550	6370	4080	2290	41.4
No. 9	1580	1650	1490	160	10.1	1630	1720	1570	150	9.2	1460	1550	1400	150	10.3	5270	5460	5150	310	5.9
No. 10	1840	2220	1500	720	39.1	1700	1880	1480	400	23.5	1580	1810	1420	390	24.7	5770	6240	4990	1250	21.7
Average	1730	....	....	342	19.5	1720	....	....	281	15.4	1540	....	....	254	16.8	5560	....	....	868	15.7
High	2130	....	....	...	....	2160	....	....	...	....	1860	....	....	...	....	6040	....	....	....	....
Low	1460	....	....	...	....	1410	....	....	...	....	1330	....	....	...	....	5200	....	....	....	....
Difference	670	....	....	...	....	750	....	....	...	....	530	....	....	...	....	840	....	....	....	....
Per Cent of Average	38.7	....	....	...	....	43.6	....	....	...	....	34.4	....	....	...	....	15.1	....	....	....	....
28-DAY TESTS																				
No. 1	3270	3430	3050	380	11.6	3100	3350	2630	720	23.2	2980	3250	2530	720	24.2	6990	7120	6820	300	4.3
No. 2	3400	3580	3180	400	11.8	3270	3490	3080	410	12.5	3190	3450	3080	370	11.6	7510	7630	7220	410	5.5
No. 3	2560	2780	2280	500	19.5	2460	2780	2210	570	23.1	2420	2600	2210	390	16.1	6340	6480	6240	240	3.8
No. 4	3010	3150	2920	230	7.6	3210	3380	3030	350	10.9	2760	3090	2510	580	21.0	6560	6740	6300	440	6.8
No. 5	3560	3640	3370	270	7.6	3460	3620	3220	400	11.6	3400	3750	3140	610	18.0	5870	6420	4660	1760	30.0
No. 6	2850	3020	2600	420	14.7	2880	3220	2320	900	31.3	2540	2780	2250	530	20.9	6820	7160	6610	550	8.1
No. 7	3100	3300	2790	510	16.4	3150	3300	2990	310	9.9	2920	3050	2750	300	10.3	7230	7530	6690	840	11.6
No. 8	4120	4460	3870	590	14.3	3890	4300	3550	750	19.3	3490	3670	3260	410	11.8	7510	7860	7240	620	8.2
No. 9	3010	3230	2930	300	10.0	2960	3030	2860	170	5.7	2780	2950	2670	280	10.1	6580	6950	6300	650	9.9
No. 10	3310	3520	3030	490	14.8	2960	3160	2810	350	11.8	3020	3320	2810	510	16.9	7210	7860	6500	1360	18.8
Average	3220	....	....	409	12.8	3130	....	....	493	15.9	2950	....	....	470	16.1	6860	....	....	717	10.7
High	4120	....	....	...	....	3890	....	....	...	....	3490	....	....	...	....	7510	....	....	....	....
Low	2560	....	....	...	....	2460	....	....	...	....	2420	....	....	...	....	5870	....	....	....	....
Difference	1560	....	....	...	....	1430	....	....	...	....	1070	....	....	...	....	1640	....	....	....	....
Per Cent of Average	48.5	....	....	...	....	45.7	....	....	...	....	36.3	....	...	...	....	23.9	....	....	....	....

The tabulation in Table III shows the average of the spreads between high and low strengths for each laboratory and for the ten laboratories expressed as percentages of the grand average strength for all laboratories.

These data show that there was a much greater spread in briquet and cube strength between the ten laboratories than within a given laboratory. Also that the percentage spread within a laboratory and between laboratories for both briquet and cube tests was greatest in the 1-day tests and decreased with age. The percentage spread in strength at a given age both within laboratories and between laboratories was in general somewhat greater for the cubes than for the briquets.

It is of interest to compare these spreads with the values in Table IV obtained in the briquet and cube tests on seven cements by seven laboratories reported in June, 1929:

TABLE III.—COMPARISON OF SPREAD IN STRENGTH WITHIN AND BETWEEN LABORATORIES.

	Spread between High and Low Strengths							
	Briquets				2-in. Cubes			
	For a Given Laboratory		For Ten Laboratories		For a Given Laboratory		For Ten Laboratories	
	Pounds	Per Cent of Average	Pounds	Per Cent of Average	Pounds	Per Cent of Average	Pounds	Per Cent of Average
1-DAY TESTS								
Cement A......	27	27	50	46	126	29	210	43
Cement B......	36	42	55	61	145	42	250	69
Cement C......	22	32	45	64	74	35	90	41
Cement D......	44	17	70	26	360	25	690	47
Average......	..	29	..	49	...	33	...	51
3-DAY TESTS								
Cement A......	33	16	45	21	269	23	350	31
Cement B......	32	16	55	27	211	19	450	42
Cement C......	35	20	40	24	178	22	290	36
Cement D......	38	10	100	26	524	13	870	22
Average......	..	16	...	24	...	19	...	33
7-DAY TESTS								
Cement A......	35	12	60	21	342	20	670	39
Cement B......	41	15	70	25	281	15	750	44
Cement C......	46	17	60	23	254	17	530	34
Cement D......	50	11	95	21	863	16	840	15
Average......	..	14	..	22	...	17	...	33
28-DAY TESTS								
Cement A......	45	12	45	12	409	13	1560	48
Cement B......	42	11	75	20	493	16	1430	46
Cement C......	35	9	80	20	470	16	1070	36
Cement D......	56	12	100	21	717	11	1640	24
Average......	..	11	..	18	...	14	....	38
Grand Average	..	18	..	28	...	21	....	39

It will be noted that the percentage spreads in both briquets and cube strengths were in general higher in the earlier series than in the present series.

Uniformity in Strengths of the Three Specimens from a Batch.—An outstanding feature of these tests is the generally good concordance in strengths of the three specimens from a batch for both the run-of-mine Ottawa sand cubes and the 1:3 standard sand briquets as shown by the mean variations in Table V. The average mean variations of the three specimens from a batch for the 5-week period in but few cases exceeded 5 per cent and in most cases were considerably less than 5 per cent, particularly in the 3, 7 and 28-day tests.

In the case of the briquets the mean variations were greater at 1 day than at later ages while in the cube tests they were about the same at all ages and were in general appreciably lower than the values obtained in the briquet tests. Laboratory No. 2 showed lowest mean variations in the briquet tests (average 2.9 per cent), while the lowest variations in the cube tests (average 2.3 per cent) were obtained by laboratory No. 7. Highest mean variations were obtained in briquet tests by laboratory No. 9 (average 4.7 per cent) and in the cube tests by laboratory No. 6 (average 5 per cent.)

TABLE IV.—SPREADS BETWEEN HIGH AND LOW STRENGTHS (FROM JUNE, 1929, REPORT).

1:3 Standard Sand Briquets			2-in. Plastic Mortar Cubes		
	Pounds	Per Cent of Average		Pounds	Per Cent of Average
2-DAY TESTS					
Normal Consistency	76	37	Run-of-Mine Ottawa Sand	687	55
Uniform Water Content	66	35	Local Sand	710	48
4-DAY TESTS					
Normal Consistency	76	29	Run-of-Mine Ottawa Sand	930	42
Uniform Water Content	63	25	Local Sand	750	30
7-DAY TESTS					
Normal Consistency	73	24	Run-of-Mine Ottawa Sand	1314	45
Uniform Water Content	69	23	Local Sand	936	29
28-DAY TESTS					
Normal Consistency	97	24	Run-of-Mine Ottawa Sand	1510	34
Uniform Water Content	78	20	Local Sand	1370	27
Grand Average	..	27		....	39

The variations in strength of the three specimens from a batch in the above tabulation are appreciably lower than those obtained for four specimens made on four different days in the tests reported in June, 1929, which were as follows:

GRAND AVERAGE MEAN VARIATIONS, PER CENT (FROM JUNE, 1929, REPORT)

Briquets						2-in. Cubes					
	2 days	4 days	7 days	28 days	Average		2 days	4 days	7 days	28 days	Average
Normal Consistency....	6.3	4.7	4.7	4.3	5.0	Run-of-Mine Sand	7.3	5.6	4.8	5.5	5.8
Uniform Water Content	5.9	4.9	4.6	4.0	4.8	Local Sand.......	6.3	5.0	5.4	4.4	5.3

It is interesting to note that the mean variations between laboratories obtained in the present tests were approximately one-half those obtained with standard sand briquets and about one-third those obtained with neat cement cubes in the tests by 47 laboratories reported in 1928.

TABLE V.—SUMMARY OF MEAN VARIATIONS OF BRIQUET AND CUBE TESTS IN THREE SPECIMENS FROM A BATCH.

Laboratory	Average Mean Variation in the Three Specimens from a Batch for a 5-Week Period, per cent																			
	Cement A				Cement B				Cement C				Cement D				Average of Four Cements			
	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days
TENSILE STRENGTH (BRIQUETS)																				
No. 1......	4.5	4.1	2.9	2.7	5.6	3.4	3.2	2.6	4.7	2.8	2.5	3.2	2.9	1.9	2.2	2.1	4.4	3.0	2.7	2.6
No. 2......	2.7	4.4	2.7	2.4	1.9	3.8	2.9	2.3	4.2	3.3	2.5	2.0	2.9	2.5	2.2	3.8	2.9	3.5	2.6	2.6
No. 3......	4.8	4.4	2.9	2.7	7.5	4.3	3.9	2.8	6.8	4.5	2.6	1.7	2.7	1.8	2.3	2.2	5.4	3.8	2.9	2.4
No. 4......	4.7	4.2	4.0	5.3	1.6	4.7	4.2	6.5	4.2	3.9	6.6	3.9	4.9	3.1	5.1	5.0	3.6	4.0	5.1	5.2
No. 5[a].....	3.2	4.1	3.7	4.2	7.8	4.7	3.8	3.9	8.4	3.4	5.2	4.8	1.5	2.8	5.2	5.1	5.2	3.8	4.5	4.5
No. 6......	5.4	6.0	4.5	3.9	9.1	3.2	4.5	3.2	5.9	6.0	6.6	3.9	3.7	3.4	2.7	2.0	6.0	4.7	4.6	3.3
No. 7......	5.3	5.5	4.6	3.6	7.1	3.8	5.6	2.7	9.5	5.3	3.9	3.1	3.9	3.2	1.7	4.0	6.5	4.5	3.9	3.4
No. 8......	4.8	2.3	3.9	2.9	2.2	5.0	5.3	3.8	5.2	4.1	3.9	4.6	4.3	5.3	4.7	3.0	4.1	4.2	4.4	3.6
No. 9......	4.1	5.6	4.4	3.7	5.3	4.5	4.8	5.2	7.9	3.7	3.8	6.9	4.0	4.6	3.8	2.5	5.3	4.6	4.2	4.6
No. 10.....	5.9	3.6	3.3	2.8	4.0	4.5	4.6	6.2	7.5	4.2	4.8	2.6	4.8	3.1	5.5	3.9	5.6	3.8	4.6	3.9
Average....	4.5	4.4	3.7	3.4	5.2	4.2	4.3	3.9	6.4	4.1	4.2	3.7	3.6	3.2	3 5	3.4	4.9	4.0	3.9	3.6
COMPRESSIVE STRENGTH (2-IN. CUBES)																				
No. 1......	2.8	3.8	3.0	3.2	5.0	2.4	2.2	2.2	3.3	2.6	2.6	4.1	2.4	1.0	1.7	1.8	3.4	2.4	2.4	2.8
No. 2......	1.8	3.5	1.9	2.9	3.3	2.6	2.6	2.8	2.6	2.3	1.4	2.9	3.3	1.8	2.3	2.2	2.8	2.6	2.0	2.7
No. 3......	3.0	3.0	5.2	6.0	4.3	3.8	4.5	4.9	4.7	2.2	6.6	8.4	2.9	5.3	4.9	4.8	3.8	3.6	5.3	6.0
No. 4......	4.0	3.9	3.8	2.7	1.5	1.4	3.9	2.9	1.3	3.2	3.1	5.4	2.0	3.8	5.9	3.3	2.2	3.1	4.2	3.6
No. 5[a].....	3.4	2.9	2.6	3.4	1.6	3.8	3.6	2.9	3.1	3.5	2.2	1.9	1.6	4.9	3.8	6.3	2.4	3.8	3.0	3.6
No. 6......	9.2	4.9	3.0	3.6	5.5	6.2	6.3	5.9	5.6	5.6	5.2	3.8	3.3	4.2	4.4	3.6	5.9	5.2	4.7	4.2
No. 7......	1.8	2.1	1.7	1.5	3.2	2.4	2.5	3.4	1.6	1.4	2.3	2.6	2.8	1.6	2.1	3.4	2.4	1.9	2.2	2.7
No. 8......	5.3	7.1	4.2	1.8	5.3	2.7	2.3	3.5	6.1	2.9	4.4	2.2	1.8	2.8	2.9	2.6	4.6	3.9	3.4	2.5
No. 9......	5.4	4.6	3.7	2.1	7.0	2.8	3.5	3.4	4.8	4.6	1.8	2.8	3.2	3.6	4.0	5.4	5.1	3.9	3.2	3.4
No. 10.....	2.0	1.4	1.9	3.6	3.9	2.7	1.9	2.8	2.7	1.4	3.8	1.9	4.8	2.5	3.4	4.1	3.4	2.0	2.8	3.1
Average....	3.9	3.7	3.1	3.1	4.1	3.1	3.3	3.5	3.6	3.0	3.3	3.6	2.8	3.2	3.5	3.8	3.6	3.2	3.3	3.5

[a] Average of four weeks.

Uniformity of Strengths Within Laboratories.—A comparison of the mean variations in briquet and cube strength for each laboratory over the 5-week period is given in Table VI.

In general these data are quite consistent for each cement and age at test. They show the differences in uniformity of the results obtained by the various laboratories. They also show that the largest variations occurred at ages of 1 day and 3 days. At 7 and 28 days the mean variations were low, in most cases averaging less than 5 per cent.

TABLE VI.—SUMMARY OF MEAN VARIATIONS OF BRIQUET AND CUBE TESTS FOR 5-WEEK PERIOD.

Values are the average deviations in the strength of the 3 specimens from a batch expressed as a percentage of the grand average strength for the 5-week period.

Laboratory	Mean Variations for 5-Week Period, Per Cent																			
	Cement A				Cement B				Cement C				Cement D				Average of Four Cements			
	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days
TENSILE STRENGTH (BRIQUETS)																				
No. 1	6.0	5.1	4.0	4.1	4.7	3.9	4.1	4.5	4.3	7.5	3.0	3.3	2.1	5.2	1.5	1.8	4.3	5.4	3.1	3.4
No. 2	3.3	5.1	2.1	1.2	8.4	2.9	0.7	2.5	4.0	3.4	2.9	2.2	3.4	3.4	2.7	2.9	4.8	3.7	2.1	2.2
No. 3	5.0	1.4	4.1	1.9	8.6	1.9	4.9	2.9	8.2	4.5	4.1	1.6	4.7	1.8	4.9	3.5	6.6	2.4	4.5	2.5
No. 4	13.0	5.9	4.3	3.5	18.6	9.2	6.8	3.6	14.5	5.3	3.7	5.8	5.0	4.3	3.4	5.0	12.8	6.2	4.6	4.5
No. 5	7.3	5.6	1.8	2.2	13.3	7.1	3.6	2.2	6.0	4.9	6.4	2.1	1.9	2.2	4.9	4.9	7.1	5.0	4.2	2.8
No. 6	10.0	5.6	4.0	4.7	18.8	4.3	2.2	5.6	12.5	8.5	9.4	3.3	8.2	0.8	2.9	4.8	12.4	4.8	4.6	4.6
No. 7	6.7	4.8	3.6	2.2	7.8	6.4	5.1	3.5	12.3	10.5	6.8	2.3	6.4	3.8	5.5	2.2	8.3	6.4	5.2	2.5
No. 8	20.0	13.0	3.6	5.5	22.9	4.0	3.4	1.3	14.0	10.6	5.4	4.4	10.4	5.3	4.7	3.8	16.8	8.2	4.3	3.8
No. 9	1.5	2.7	6.3	3.4	9.6	5.5	6.0	4.5	8.4	5.1	6.3	2.1	2.0	3.0	0.9	2.0	5.4	4.1	4.9	3.0
No. 10	6.4	5.1	3.2	3.5	17.8	6.5	5.9	4.6	8.0	3.7	4.0	2.8	7.4	2.7	1.6	2.2	9.9	4.5	3.7	3.3
Average	7.9	5.4	3.7	3.2	13.0	5.2	4.3	3.5	9.2	6.4	5.2	3.0	5.2	3.2	3.3	3.3	8.8	5.0	4.1	3.3
COMPRESSIVE STRENGTH (2-IN. CUBES)																				
No. 1	3.1	9.4	1.5	3.2	4.6	3.6	3.9	8.5	0.7	3.7	6.2	6.2	2.4	6.1	3.2	1.3	2.7	5.7	3.7	4.8
No. 2	2.3	2.3	2.2	3.7	6.1	3.5	3.6	4.6	7.6	3.2	4.5	3.4	6.3	1.7	2.0	1.6	5.6	2.7	3.1	3.3
No. 3	7.4	7.4	7.4	7.3	8.9	2.3	5.1	6.7	17.1	6.8	6.1	5.0	5.1	5.9	6.3	1.5	9.6	5.6	6.2	5.1
No. 4	11.3	8.3	5.1	2.0	10.4	5.1	4.4	3.0	6.3	7.3	4.0	8.0	8.3	5.4	4.9	2.0	9.1	6.5	4.6	3.8
No. 5	9.2	6.4	8.6	2.8	14.8	4.5	6.2	4.2	6.8	6.7	6.8	5.3	7.5	1.7	1.5	10.3	9.6	4.8	5.8	5.6
No. 6	10.8	8.5	4.3	5.2	16.8	12.6	2.4	7.8	10.4	20.0	8.3	8.3	13.6	4.4	4.6	2.4	12.9	11.4	4.9	5.9
No. 7	2.6	1.8	4.7	6.1	2.6	5.4	5.0	3.4	2.1	2.6	1.5	3.5	3.2	2.9	4.7	3.0	2.6	3.2	4.0	4.0
No. 8	14.4	13.3	9.8	3.9	23.5	15.3	8.3	6.3	15.0	17.3	3.7	3.7	14.8	7.1	8.4	2.6	16.9	13.2	7.6	4.1
No. 9	10.7	9.7	3.7	2.8	20.5	2.5	3.4	1.7	14.5	7.0	2.6	2.9	6.7	2.0	1.7	2.5	13.1	5.3	2.8	2.5
No. 10	15.6	8.5	10.2	6.3	21.7	7.6	8.5	4.3	16.4	6.4	8.8	5.4	12.9	3.6	5.3	5.2	16.7	6.5	8.2	5.3
Average	8.7	7.6	5.8	4.3	13.0	6.2	5.1	5.0	9.7	8.1	5.2	5.2	8.1	4.1	4.3	3.2	9.9	6.5	5.1	4.4

Laboratories Nos. 3, 5, 6, 8, and 10 obtained greater uniformity in the briquet tests than in the cube tests. Laboratories Nos. 1, 2, 4, and 9 obtained about the same degree of uniformity in both types of test while laboratory No. 7 obtained most concordant results with the cubes. In general there appears to be little choice between the two types of test so far as uniformity within a given laboratory is concerned.

Uniformity in Strength Between Laboratories.—The following tabulation gives the average variations in the strengths obtained by individual laboratories from the grand average strengths for all laboratories both for these tests and those made by seven laboratories along similar lines which were reported in June, 1929:

MEAN VARIATIONS IN STRENGTHS BETWEEN LABORATORIES, PER CENT.

	Present Series (Ten Laboratories)					Report of June, 1929 (Seven Laboratories)				
	1 day	3 days	7 days	28 days	Average	2 days	4 days	7 days	28 days	Average
Briquets..........	11.3	5.5	4.5	4.0	6.3	10.4	7.3	6.5	6.1	7.6
Cubes.............	10.1	7.9	7.1	8.3	8.4	14.6	10.1	11.3	9.1	11.3

While these results show a decided improvement over those obtained in the previous series along similar lines, they suggest that before it will be possible to obtain greater refinement in methods of test, it will be necessary to obtain more refinement in laboratory equipment and control.

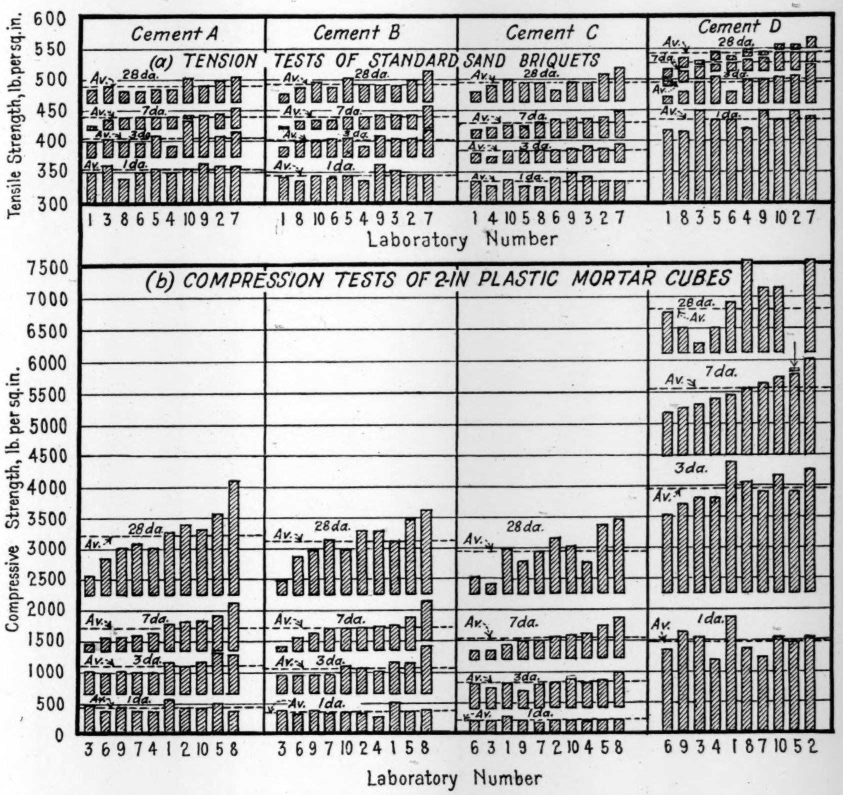

FIG. 1.—Comparison of Average Briquet and Cube Strengths for Ten Laboratories. Laboratories arranged in order of ascending 7-day strengths for each cement. Data from Tables I and II.

It will be noted that the mean variations for the 10 laboratories in the present series are appreciably higher than the weekly variations in strength for individual laboratories which were discussed in the preceding section.

Relative Strengths at Different Ages.—The following data show the average briquet and cube strengths for the ten laboratories for each cement together with the relative strengths for each cement based on the grand average strengths. Included in the table are the relative strengths for each cement at each age based on the 7-day strengths:

	Briquets				Cubes			
	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days
AVERAGE STRENGTHS FOR TEN LABORATORIES, LB. PER SQ. IN.								
Cement A..........	110	210	280	380	440	1120	1730	3220
Cement B..........	90	205	280	385	360	1070	1720	3130
Cement C..........	70	170	260	390	220	810	1540	2950
Cement D..........	270	390	455	485	1470	3960	5560	6860
Grand Average......	135	244	319	410	622	1740	2638	4040
RELATIVE STRENGTHS AS PERCENTAGE OF GRAND AVERAGE STRENGTHS								
Cement A..........	81	86	88	93	71	64	66	80
Cement B..........	67	84	88	94	58	62	65	78
Cement C..........	52	70	81	95	35	47	58	73
Cement D..........	200	160	143	118	236	227	211	168
RELATIVE STRENGTHS AS PERCENTAGE OF 7-DAY AVERAGE STRENGTHS								
Cement A..........	39	75	100	136	26	65	100	186
Cement B..........	32	73	100	137	21	62	100	182
Cement C..........	27	65	100	150	14	53	100	192
Cement D..........	59	86	100	107	26	71	100	123

The above data are shown graphically in Figs. 2 and 3. The diagrams in Fig. 2 show, as has been pointed out in other reports along similar lines, that the briquet test gives relatively high tensile strengths for cements which give low compressive strength and relatively low tensile strengths for cements which test high in compression. As concrete tests were not made in this series, it is not possible to tell whether the cubes or the briquets are the better indicators of concrete strength.

In Table VII briquet and cube strengths at each age are expressed as percentages of the 28-day strengths. Data from this table are plotted in Fig. 4. The relative strengths in Table VII and Fig. 4 are of interest in making comparisons of the test results since differences in relative strengths are due to differences in manipulation and in conditions within the various laboratories and not to differences in cements.

A study of these data shows that the following laboratories generally obtained the highest or lowest relative strength values:

	BRIQUETS	CUBES
Laboratories obtaining high relative strengths.....	3, 9	1, 3
Laboratories obtaining low relative strengths......	1, 4, 8	8

Some of the laboratories in the above tabulation did not maintain as uniform temperature and humidity conditions (see Table IX) during the period of the tests as the others, which may account in part for the results which they obtained. Differences in manipulation and methods of testing may also be partly responsible for the differences found in the relative strength values for the 10 laboratories.

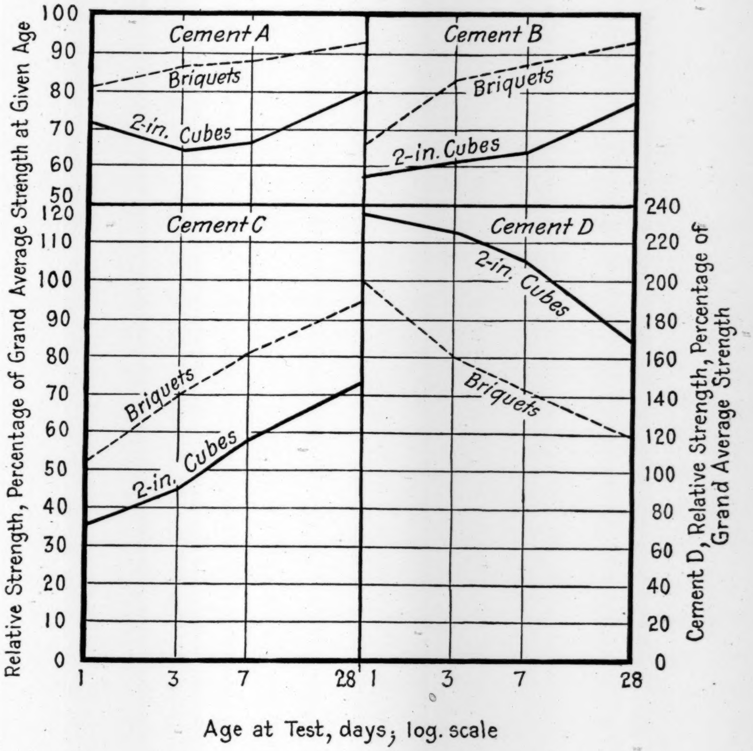

FIG. 2.—Relative Strengths at Different Ages, Per Cent of Grand Average Strength.

Miscellaneous Tests.—Table VIII summarizes the results of miscellaneous tests on the various cements. The maximum spread in normal consistency determinations was 2.3 per cent for cement A, 2.2 per cent for cement B, 3 per cent for cement C and 4 per cent for cement D. Laboratory No. 1 reported highest normal consistencies. If the results from this laboratory are omitted the spreads are very materially reduced.

Three laboratories did not specify the type of needle used in making time of setting tests so that it is not possible to make worth-while comparisons of time of setting results.

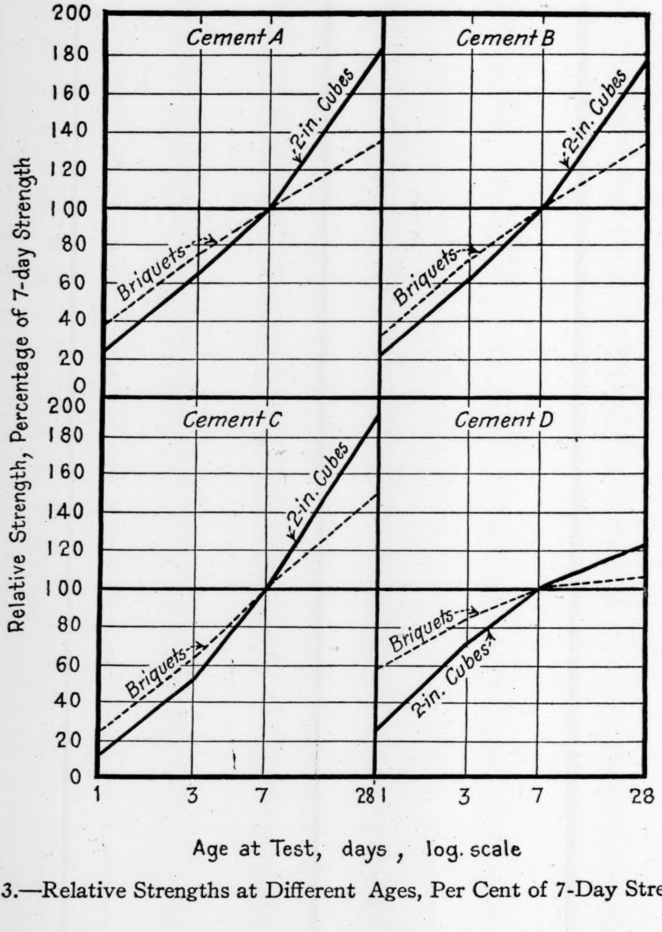

FIG. 3.—Relative Strengths at Different Ages, Per Cent of 7-Day Strength.

Most of the laboratories obtained complete penetration of the pat with the Vicat needle at 1 hour in the penetration tests. In only a few cases was any penetration obtained at 6 hours.

Sieve analyses of the run-of-mine sand reported by the different laboratories were quite uniform except in the case of laboratory No. 10, which used a different lot of the run-of-mine material.

Perhaps the data of most interest in this table are the flow values. A considerable range in flows was obtained, due either to conditions surrounding the tests or to differences in manipulation by the various operators. The spread in the average flow for cement A ranged from 131 to 157, for cement B from 121 to 152, for cement C from 127 to 162, and for cement D from 136 to 175. The greatest spread in flow was obtained for cement D.

TABLE VII.—RELATIVE STRENGTHS AT EACH AGE.

Laboratory	Average Strengths Expressed as a Percentage of the 28-Day Strengths															
	Cement A				Cement B				Cement C				Cement D			
	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days	1 day	3 days	7 days	28 days
BRIQUET TESTS																
No. 1	27	53	68	100	24	51	69	100	19	44	65	100	54	79	91	100
No. 2	30	54	72	100	24	52	71	100	18	42	66	100	58	80	95	100
No. 3	32	56	72	100	28	54	75	100	22	47	70	100	65	85	97	100
No. 4	27	50	76	100	18	48	73	100	14	39	64	100	48	80	94	100
No. 5[a]	30	58	76	100	22	52	69	100	14	43	65	100	55	84	92	100
No. 6	27	53	75	100	23	56	72	100	22	46	75	100	57	76	96	100
No. 7	29	56	76	100	21	55	73	100	15	43	67	100	52	83	92	100
No. 8	22	55	75	100	19	53	71	100	13	44	67	100	49	77	90	100
No. 9	34	59	75	100	33	58	75	100	24	45	69	100	60	82	96	100
No. 10	27	53	70	100	23	51	69	100	19	41	63	100	53	79	95	100
Average	29	55	74	100	23	53	72	100	18	43	67	100	55	80	94	100
High	34	59	76	...	33	58	75	...	24	47	75	...	65	85	97	...
Low	22	50	68	...	18	48	69	...	13	39	63	...	48	76	90	...
2-IN. CUBE TESTS																
No. 1	18	39	54	100	17	37	51	100	9	28	48	100	31	73	91	100
No. 2	13	33	52	100	10	33	52	100	7	25	49	100	20	57	80	100
No. 3	18	40	57	100	15	39	57	100	9	31	56	100	24	60	84	100
No. 4	12	34	55	100	8	31	54	100	7	30	58	100	18	58	83	100
No. 5[a]	14	37	54	100	10	33	54	100	6	26	51	100	25	67	99	100
No. 6	14	34	54	100	11	33	54	100	9	31	52	100	20	52	76	100
No. 7	12	33	52	100	10	31	54	100	6	27	51	100	17	54	78	100
No. 8	10	31	52	100	9	36	55	100	6	28	53	100	18	54	75	100
No. 9	15	34	53	100	12	33	55	100	8	25	52	100	25	57	80	100
No. 10	14	35	56	100	12	37	57	100	7	28	52	100	21	58	80	100
Average	14	35	54	100	12	34	54	100	8	28	52	100	22	59	83	100
High	18	40	57	...	17	39	57	...	9	31	58	...	31	73	99	...
Low	10	31	52	...	8	31	51	...	6	25	48	...	17	52	75	...

[a] Average of four weeks.

Table IX gives temperature and humidity data for each laboratory during the period of making and curing the test specimens. It will be noted that except for laboratories Nos. 3 and 8 the temperature of the mixing water was 70° F. It is difficult to understand why all laboratories could not have brought the mixing water to 70° F. before making the specimens.

TABLE VIII.—SUMMARY OF MISCELLANEOUS TESTS ON CEMENTS.

Laboratory	Water, Normal Consistency, per cent	Time of Set				Penetration Vicat Needle, mm.		Residue on No. 200 Sieve, per cent	Soundness Over Boiling Water	Run-of-Mine Sand					Average Flow of Plastic Mortar
		Gillmore		Vicat						Retained on Sieve, per cent				Fineness Modulus	
		Initial h. m.	Final h. m.	Initial h. m.	Final h. m.	1 hour	6 hours			No. 100	No. 50	No. 30	No. 16		
CEMENT A															
No. 1	24.8	.. ..	....	2:00[a]	4:50[a]	40	...	15.0	...	95.2	78.8	8.3	0	1.82	131
No. 2	22.5	4:10[a]	7:30[a]	....	....	40	0.5	13.6	OK	95.0	73.0	7.0	0	1.75	157
No. 3	23.5	3:00	6:10	1:45	5:00	37	0	14.8	OK	....	....	...	..	1.86	151
No. 4	....	....	(No miscellaneous tests made)					....	...	95.0	76.0	6.0	0	1.77	151
No. 5	23.6	....	....	3:40	5:25	..	...	12.1	OK	....	....	....	....	.....	132
No. 6	23.0	2:00	5.00	3:00	5.25	40	0	14.8	OK	95.5	81.7	7.5	0	1.85	144
No. 7	23.5	4:25	8:00	2:45	7:20	40	0	....	OK	97.0	83.0	9.0	0	1.89	147
No. 8	23.7	3:50[a]	6:20[a]	....	....	..	...	12.4	OK	97.7	83.7	8.8	0	1.90	157
No. 9	24.0	3:25	6:45	2:10	5:30	40	0	15.0	OK	96.2	....	...	..	1.79	131
No. 10	23.2	....	....	1:50	5:20	40	0	12.2	OK	98.0	64.0	0	0	1.62	128
CEMENT B															
No. 1	25.2	....	....	3:10[a]	6:40[a]	40	...	16.0	...	....	....	...	..	....	123
No. 2	23.5	5:20[a]	8:30[a]	....	....	40	1.5	13.7	OK	....	....	...	..	....	152
No. 3	23.0	3:20	6:25	2:10	5:10	39	0	14.5	OK	....	....	...	..	....	150
No. 4	....	....	....	....	....	..	...	....	...	....	....	...	..	....	149
No. 5	24.4	....	....	2:45	4:00	..	...	13.7	OK	....	....	...	..	....	127
No. 6	23.0	4:00	6:00	4:40	6:40	40	0	14.2	OK	....	....	...	..	....	140
No. 7	23.5	5:50	9:15	4:15	8:50	40	0.5	....	S.W.[b]	....	....	...	..	....	143
No. 8	23.4	4:45[a]	7:00[a]	....	....	..	...	11.0	OK	....	....	...	..	....	150
No. 9	23.0	4:05	9:30	2:50	6:50	40	0	15.0	OK	....	....	...	..	....	130
No. 10	23.5	....	....	3:50	6:35	40	0.5	11.7	OK	....	....	...	..	....	121
CEMENT C															
No. 1	26.0	....	....	2:00[a]	5:10[a]	40	...	13.0	...	....	....	...	..	....	133
No. 2	23.8	4:40[a]	7:55[a]	....	....	40	0.5	9.1	OK	....	....	...	..	....	162
No. 3	23.5	2:40	5:40	1:20	4:25	40	0	11.5	OK	....	....	...	..	....	162
No. 4	....	....	....	....	....	..	...	....	...	....	....	...	..	....	141
No. 5	23.6	....	....	3:25	4:55	..	...	8.3	OK	....	....	...	..	....	134
No. 6	23.0	2:30	5:50	3:50	6:00	40	0	9.4	OK	....	....	...	..	....	144
No. 7	24.0	4:40	8:15	3:10	8:00	40	0	....	OK	....	....	...	..	....	148
No. 8	24.0	4:05[a]	6:40[a]	....	....	..	...	7.0	S.C.[c]	....	....	...	..	....	164
No. 9	24.0	3:25	8:15	2:10	6:40	40	0	10.8	S.C.[c]	....	....	...	..	....	133
No. 10	24.5	....	....	2:55	5:55	40	0	7.4	S.C.[c]	....	....	...	..	....	127
CEMENT D															
No. 1	26.0	....	....	1:00[a]	2:25[a]	35	...	4.0	...	....	....	...	..	....	147
No. 2	22.0	2:15[a]	3:50[a]	....	....	40	0	3.8	OK	....	....	...	..	....	173
No. 3	24.0	2:10	5:20	1:10	4:25	40	0	2.2	OK	....	....	...	..	....	169
No. 4	....	....	....	....	....	..	...	....	...	....	....	...	..	....	171
No. 5	23.6	....	....	1:45	2:30	..	...	1.9	OK	....	....	...	..	....	136
No. 6	24.0	1:45	3:15	0:50	2:45	16	0	3.8	OK	....	....	...	..	....	163
No. 7	24.0	2:10	3:30	1:20	3:05	40	0	....	OK	....	....	...	..	....	158
No. 8	24.3	1:50[a]	2:55[a]	....	....	..	...	2.4	OK	....	....	...	..	....	175
No. 9	24.5	2:25	4:10	1:20	3:00	40	0	2.8	OK	....	....	...	..	....	144
No. 10	23.0	....	....	0:55	3:05	29	0	3.1	OK	....	....	...	..	....	144

[a] Type of needle not specified.
[b] Slight warping.
[c] Slight checking.

TABLE IX.—TEMPERATURE AND HUMIDITY DATA.

Laboratory	Date Made (1929)	Temperature, deg. Fahr.					Relative Humidity, per cent		
		Mixing Water	Air of Room		Curing Water		Mixing Room	Moist Closet	Moist Room
			Mixing	Moist	Maximum	Minimum			
No. 1	August 5, 6	70	76	72, 73	78	70	..	100	100
	August 12, 13	70	76	74, 73	..	..	..	...	...
	August 19, 20	70	76	72	..	..	..	...	...
	August 26, 27	70	76	74, 72	..	..	..	...	...
	September 3, 4	70	78	74	..	..	..	...	...
No. 2	July 26	70	75	70 ± 2	71	69	68	100	100
	August 2	70	75	..	..	..	50	...	...
	August 9	70	75	..	..	..	66	...	...
	August 16	70	73	..	..	..	58	...	...
	August 23	70	75	..	..	..	74	...	...
No. 3	August 5, 6	..	..	..	76	63	..	100	100
	August 12, 13	..	..	..	..	..	..	...	...
	August 19, 20	73, 71	74	74	..	..	51, 66	...	...
	August 26, 27	73	80, 74	76, 74	..	..	41, 51	...	...
	September 2, 3	75, 76	83, 84	76, 78	..	..	52, 58	...	...
No. 4	August 7, 9	70	86, 66	73, 64	79	59	..	100	...
	August 14, 16	70	78, 75	68, 70	..	..	..	97	...
	August 19, 20	70	70, 66	63, 70	..	..	..	100	...
	August 21, 23	70	70	70	..	..	..	100	...
	August 27, 28	70	70	70	..	..	..	100	...
No. 5	November 18 to December 9	70 to 74	68 to 74	66 to 76	75	63	44 to 59	96 Av.	...
No. 6	September 6, 7	70	76, 77	73	79	67	81, 82	98	98
	September 12, 13	70	75, 72	72, 71	..	..	83, 92	97, 99	96, 98
	September 19, 20	70	68, 69	69, 69	..	..	74, 79	99	99
	September 26, 27	70	70, 70	70	..	..	92	99	99
	November 3, 4	70	66, 66	66, 68	..	..	53, 63	99, 99	99, 99
No. 7	August 15	70	70	71	70	70	66	100	100
	August 19	70	70	71	..	..	68	...	...
	August 28	70	70	71	..	..	72	...	...
	September 6	70	70	71	..	..	68	...	...
	September 11	70	69	70	..	..	67	...	...
No. 8	September 24, 25	67, 70	67, 70	74, 70	75	61	..	100	...
	September 30; October 1, 2	70, 69, 70	71, 73, 73	65, 75, 72	..	..	..	...	...
	October 7, 8, 9	66, 67, 64	65, 66, 66	65, 75, 60	..	..	..	...	...
	October 22, 23	72, 69	74, 70	73, 68	..	..	..	...	...
	October 28, 29	68, 71	67, 73	65, 70	..	..	..	...	...
No. 9	August 29	72	71	72	74	69	72	...	...
	September 4	71	79	74	..	..	59	...	...
	September 11	72	72	72	..	..	50	...	...
	September 18	72	71	71	..	..	47	...	...
	September 25	71	72	72	..	..	79	...	...
No. 10	July 29	70	89	83	83	56	..	96	...
	August 5	68	88	80	..	..	..	...	...
	September 5	70	88	81	..	..	..	...	...
	September 9	68	86	81	..	..	..	...	...
	September 16	70	79	70	..	..	..	...	...

The temperature of the moist room and mixing room in many laboratories was several degrees higher than 70° F. Temperature of curing water showed a considerable range in some cases, particularly in the case of laboratory No. 10, where a range from a minimum of 58° F. to a maximum of 83° F. was reported. In general, moist closet and moist room humidities were close to 100 per cent.

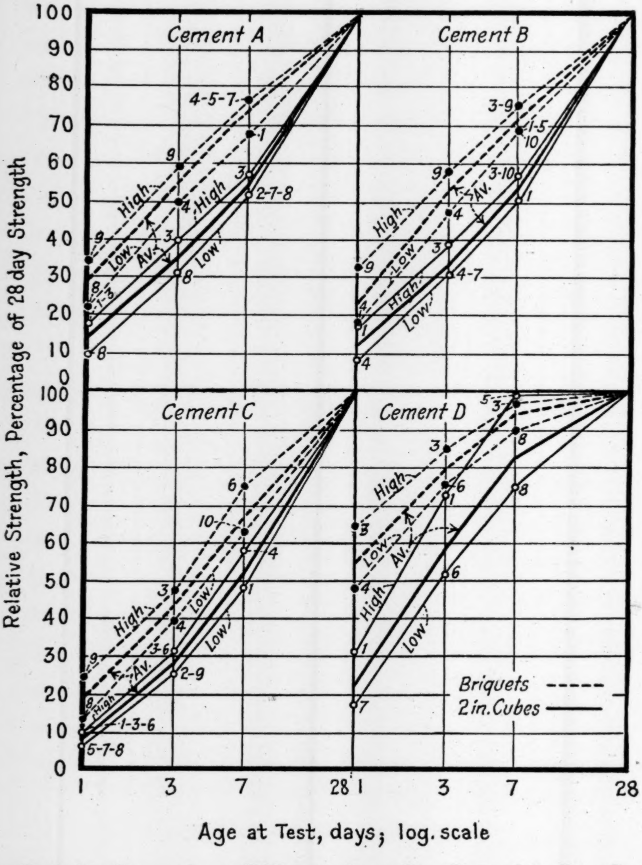

FIG. 4.—Relative Strengths at Different Ages, Per Cent of 28-Day Strength.

If different laboratories are to obtain comparable results in tests of cement, provision must be made for closer control of temperatures and humidities.

REPORT OF COMMITTEE C-3
ON
BRICK

Committee C-3 on Brick held two general meetings during the past year, at Atlantic City on June 25, 1929, and at Washington on April 1, 1930. The committee is making several recommendations with reference to the standards and tentative standards under its jurisdiction, as indicated below:

Proposed Revision of Standard.—The committee recommends for immediate adoption the following revision of the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 29).[1] The committee accordingly asks for the necessary nine-tenths vote.

Section 2 (a).—Change the second column heading in the table of physical requirements to read as follows by the addition of the italicized words:

> Compressive Strength (bricks flatwise), lb. per sq. in., *mean gross area*

Change the third column heading in the table of physical requirements to read as follows by the addition of the italicized words:

> Modulus of Rupture (bricks flatwise), lb. per sq. in. *gross area.*

Section 3.—Change the next to the last sentence to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> In general, two samples of 10 brick each shall be tested for [every] *each* 100,000 bricks contained in the lot under consideration; but where the total quantity exceeds 500,000, [the number of samples tested may be fewer, provided that they shall be distributed as uniformly as practicable over the entire lot] *one sample of 10 brick from each 100,000 shall be tested.*

Proposed Revision of Tentative Standard.—The committee recommends that the Tentative Methods of Testing Brick (Compression, Flexure and Absorption) (C 67 – 28 T)[2] be revised as follows and continued as tentative:

Section 7.—Change the first paragraph to read as follows by the addition of the italicized words and the omission of the word in brackets:

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[1] 1929 Supplement to Book of A.S.T.M. Standards, p. 127.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 854 (1928); also 1929 Book of A.S.T.M Tentative Standards, p. 242.

7. The compressive strength in pounds per square inch shall be reported as the total maximum load, W, in pounds, indicated by the testing machine, divided by the [area] *average of the gross areas of the top and bottom of the specimen*, A, in square inches, of the [minimum] section of the specimen perpendicular to the line of application of the load.

Advancement of Tentative Standards to Standard.—A complete revision of the Tentative Specifications for Sand-Lime Building Brick (C 73 – 28 T)[1] has been prepared by Subcommittee IX on Sand-Lime Brick (Allen G. Walton, chairman), to bring the requirements as to physical properties of these specifications in line with the Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 29). The revised specifications are appended hereto.[2] The committee recommends that they be adopted as standard.

It is also recommended that the Tentative Specifications for Paving Brick (C 7 – 29 T)[3] be advanced to standard without revision.

Tentative Standard Continued as Tentative.—Pending completion of a laboratory investigation of the properties of concrete brick, the committee recommends that the Tentative Specifications for Concrete Building Brick (C 55 – 28 T) be continued as tentative without revision.

The recommendations appearing in this report have been submitted to letter ballot of the committtee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS OF STANDARD			
Standard Specifications for Building Brick (Made from Clay or Shale) (C 62 – 29)......	32	1	1
II. PROPOSED REVISIONS OF TENTATIVE STANDARD			
Tentative Methods of Testing Brick (Compression, Flexure and Absorption) (C 67 – 28 T)	32	1	1
III. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Specifications for Sand-Lime Building Brick (C 73 – 28 T), as revised........	31	0	3
Tentative Specifications for Paving Brick (C 7 – 29 T), without revision...............	32	1	1

This report has been submitted to letter ballot of the committee, which consists of 38 members; 34 members returned their ballots, of whom 33 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

T. R. LAWSON,
Chairman.

J. W. MCBURNEY,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 840 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 231.

[2] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p.168.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 628 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 233.

EDITORIAL NOTE

The proposed immediate revision of the Standard Specifications for Building Brick (Made from Clay or Shale) was approved at the annual meeting by a unanimous vote and subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 166.

The proposed revision of the Tentative Methods of Testing Brick (Compression, Flexure and Absorption) was accepted. The methods in their revised form appear on page 1033.

The Tentative Specifications for Sand-Lime Building Brick, as revised, and for Paving Brick, without revision, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 168 and 170, respectively.

REPORT OF COMMITTEE C-4

ON

CLAY AND CEMENT-CONCRETE PIPE

Since the 1929 annual meeting of the Society, Committee C-4 has held one meeting, at the Society's headquarters in Philadelphia, April 11, 1930. Another meeting will be held prior to the presentation of this report to the Society.

The present membership of the committee is 31, which is the full number fixed by the rules of the committee, classified as 17 consumers and general interests, and 14 producers.

At the meeting held April 11, 1930, rules of procedure, or by-laws, were adopted under which the advisory committee was continued; the subcommittee on clay pipe was changed to Technical Committee A on Clay Pipe, and the subcommittee on cement-concrete pipe, to Technical Committee B on Concrete Pipe.

The Advisory Committee consists of the three committee officers, the chairman of the two technical committees, and a producer member from each technical committee.

Each technical committee has a chairman and a secretary and consists of 14 members including these officers of which 7 including the chairman, are consumers and general interests, and 7 are producers. Each may have such subcommittees as may be found necessary.

The committee is preparing a revision of the Standard Specifications for Clay Sewer Pipe (C 13 – 24), and also a revision of the Standard Specifications for Cement-Concrete Sewer Pipe (C 14 – 24). The purpose of the committee is to strengthen and broaden the specifications, and to make them more clear and definite on several points and also to make them conform more closely to the present needs of engineers and the advancing methods of pipe manufacture.

Substantial progress has been made in this work but further study is necessary. In the clay pipe specifications because of the difference in clays from different parts of the country it is felt that considerable tolerance may be required in the matter of permissible variations. Technical Committee A has this matter under investigation.

In connection with the preparation of new specifications for reinforced concrete pipe, a field survey and study of existing reinforced-concrete pipe structures, etc., involving an examination to date of 191 such structures 24 to 108 in. in diameter has been in progress, for the purpose of securing data of performance under service conditions, as a check and guide in specification preparation. From data thus secured, essential features of the specifications have been determined, and proposed specifications agreed upon by the committee. The committee accordingly recommends that the proposed Tentative Specifications for Reinforced-Concrete Pipe, appended hereto,[1] be accepted for publication as tentative.

The Joint Concrete Culvert Pipe Committee's specifications for culvert pipe were officially referred to this committee on April 29, 1929, on behalf of the Executive Committee which "desired that Committee C-4 review the specifications and submit its recommendations respecting approval of the specifications by the Society." These specifications have been reviewed during the year, and at the meeting held April 11, 1930, certain editorial revisions were adopted, which were ordered sent to letter ballot of the members. The text of these specifications as changed by the editorial revisions, entitled Proposed Tentative Specifications for Reinforced-Concrete Culvert Pipe, are appended hereto.[2] It is recommended that the specifications with these editorial changes be accepted for publication as a tentative standard of the Society.

The committee recommends that the Tentative Specifications for Required Safe Crushing Strength of Sewer Pipe to Carry Loads from Ditch Filling (C 15 - 17 T)[3] be withdrawn. The reasons for withdrawal, are that these specifications, which have remained tentative since 1917 without being revised or adopted as standard, are not now in line with the work of this committee, and although they contain valuable data, they do not fit into the committee's work as now constituted.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

The recommendations presented in this report have been submitted to letter ballot of the committee, which consists of 31 members, with the following results:

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[1] See p. 1040.—Ed.

[2] See p. 1051.—Ed.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 20, Part I, p. 603 (1920); also 1929 Book of A.S.T.M. Tentative Standards, p. 249.

Items	Affirm-ative	Neg-ative	Not Voting
I. PROPOSED TENTATIVE STANDARDS			
Tentative Specifications for Reinforced-Concrete Pipe[a]	18	3	3
Tentative Specifications for Reinforced-Concrete Culvert Pipe[b]	18	3	3
II. WITHDRAWAL OF TENTATIVE STANDARD			
Tentative Specifications for Required Safe Crushing Strength of Sewer Pipe to Carry Loads from Ditch Filling (C 15 – 17 T)	21	1	1

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[a] The classified vote on the Tentative Specifications for Reinforced-Concrete Pipe was as follows: Affirmative: 8 producers, 10 consumers; negative: 1 producer, 2 consumers; not voting: 2 producers, 1 consumer.

[b] The classified vote on the Tentative Specifications for Reinforced-Concrete Culvert Pipe was as follows: Affirmative: 6 producers, 12 consumers; negative: 3 producers, 0 consumers; not voting: 2 producers, 1 consumer.

This report has been submitted to letter ballot of the committee, which consists of 31 members, 23 members returned their ballots; of whom 15 have voted affirmatively and 7 negatively.

Respectfully submitted on behalf of the committee,

GEORGE T. HAMMOND,
Chairman.

ANSON MARSTON,
Vice-Chairman.

E. S. RANKIN,
Secretary.

EDITORIAL NOTE

The proposed Tentative Specifications for Reinforced Concrete Pipe and for Reinforced-Concrete Culvert Pipe were accepted for publication as tentative and appear on pages 1040 and 1051, respectively.

The withdrawal of the Tentative Specifications for Required Safe Crushing Strength of Sewer Pipe to Carry Loads from Ditch Filling was approved.

REPORT OF COMMITTEE C-5

ON

FIRE TESTS OF MATERIALS AND CONSTRUCTION

During the past year Committee C-5 has continued its work on development of standard methods of conducting fire tests of lumber, applicable both to chemically-treated lumber and to lumber in its natural state. The committee held one meeting since the last annual meeting of the Society, namely, on March 21, 1930; another meeting will be held during the annual meeting.

As a result of the research work which has been conducted in the interest of the work of the committee prior to and during the last year a Proposed Method of Test for Fire-Retardant Treated Wood has been drafted and given extended discussion during the committee meetings. Certain members of the committee who have a very active interest in the subject have not as yet had opportunity to give the proposed method a practical trial, and believe that it should not be recommended for acceptance by the Society as a tentative standard until it has been proved meritorious by practical application to the testing of commercial treated-lumber products. Further, it is the opinion of certain members of the committee that it may appear best not to confine its recommendations to a single test, but to include more than one in its prospective recommendations for a standard method of testing.

Wishing to invite comment on the work which has been accomplished to date, the committee recommends that the above-mentioned proposed Method of Test for Fire-Retardant Treated Wood, which is appended hereto, be published as information.

Committee C-5 has responsibility for only one existing tentative standard, the Tentative Specifications for Fire Tests of Building Construction and Materials (C 19 – 26 T). In the earlier drafts, these specifications and tests were the work of Committee C-5. Later they were taken in hand and developed into their present form by a Sectional Committee functioning under the procedure of the American Standards Association, formerly the American Engineering Standards Committee. Since their adoption as tentative by the Society they have been used by certain testing bodies for guidance in conducting tests on subjects which lie within their scope. But they are applicable to test subjects in very considerable variety, and there are many subjects on which they have not as yet been given adequate practical trial. The sectional committee, which conducted the later development work on the specifications, has not met during the past year for revision or extension of its past work; but during its later sessions recognized that frequent revision would be unwise because of its effect on the status of classifications derived from tests conducted in accordance with the present text. Committee C-5 continues to believe that the specifications should remain in their present form until they have been applied to testing problems in wider variety than are of record thus far; and therefore recommends that the Tentative Specifications C 19 – 26 T be continued as tentative without revision.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 14 members; 13 members returned their ballots, of whom 11 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

RUDOLPH P. MILLER,
Chairman.

FITZHUGH TAYLOR,
Secretary.

APPENDIX

PROPOSED METHOD OF TEST FOR FIRE-RETARDANT TREATED WOOD

1. *Scope.*—This method of test is intended for wood treated or processed to reduce its characteristic fire hazards as used in buildings or for other purposes.

APPARATUS

2. *Apparatus.*—The standard fire-tube apparatus of the U. S. Forest Products Laboratory shall be used. The apparatus [1](see Fig. 1) consists essentially of an open galvanized iron tube in which the specimen suspended from a balance arm is burned. To the balance arm is attached a pointer which indicates on a chart the percentage of loss in weight as the burning proceeds. The apparatus is also equipped with a thermocouple and pyrometer for determining the temperature at the top of the tube. The specimen, shown leaning against the chart support, is hung in the center of the tube during the test. A gas flame is applied to the lower fourth of the specimen by means of a Bunsen burner. A wire screen attached to the bell-shaped bottom of the tube serves to catch burning embers that fall during the test. A double row of slots on opposite sides of the tube allows the entrance of air and permits the operator to watch the progress of the burning.

SAMPLING

3. *Sampling* (*a*).—Material for sampling shall be selected from all portions of the shipment, care being taken to secure representative ranges as regards rate of growth, density, and heartwood and sapwood if both are present. Not less than five pieces shall be taken from each 5000 ft. or fraction thereof of lumber treated or received. Each species and thickness delivered may at the option of the purchaser be considered a separate shipment and sampled accordingly.

(*b*) When the material to be tested is received in lengths larger than necessary for obtaining test specimens, sample pieces so far as possible shall be 5 ft. or more in length. When the material to be tested is received in lengths generally less than necessary for test specimens, sample pieces shall be selected from those of maximum length.

(*c*) Unless otherwise specified by the purchaser, the sampling shall be done at the point of delivery.

TEST SPECIMENS

4. *Preparation of Test Specimens* (*a*).—Test specimens shall be prepared with reference to the general class of purposes for which the material is to be used, as follows:

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[1] For a more detailed description of this apparatus see "A New Test for Measuring the Fire Resistance of Wood" by T. R. Truax and C. A. Harrison, *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 973 (1929).

Class A.—Materials in this class include those of less than 2 in. in thickness to be used for worked lumber, in which an average, rather than a specific minimum of treatment effect is desired (Note). Test pieces 40 in. in length shall be taken from the samples as shown in Fig. 2 (*a*). When samples are not long enough for a complete test specimen, they shall be cut into lengths which can be combined to form a complete specimen. Pieces so joined shall have a scarf joint, slope 1 in 5, and shall be nailed together with small finishing nails. The lower end of a specimen thus prepared shall be that resulting from a cut near the center of a sample piece.

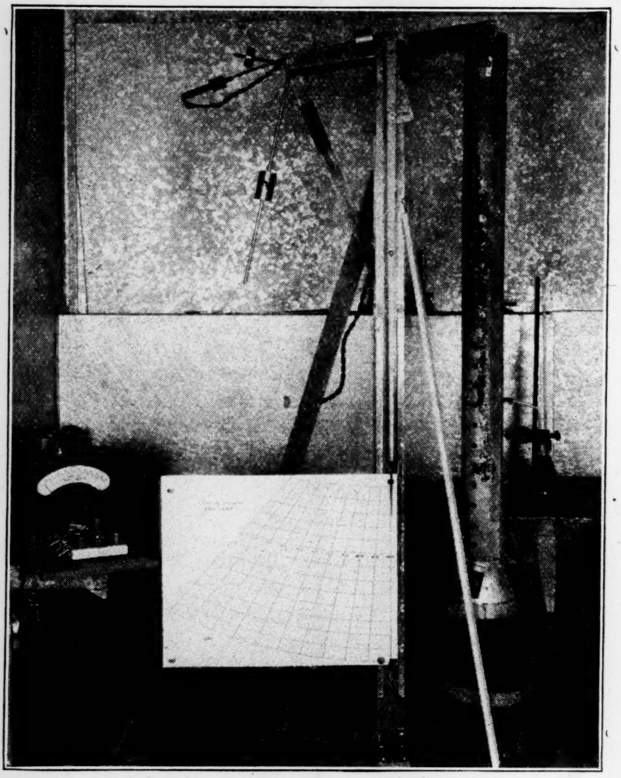


FIG. 1.—Fire-Tube Test Apparatus.

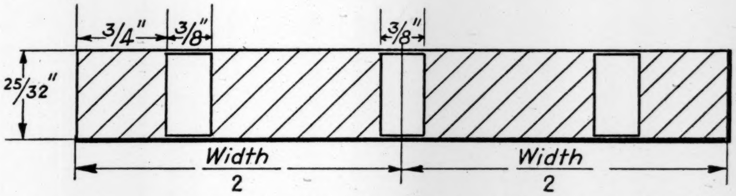
NOTE.—*Example:* Finish flooring, trim, moldings, paneling.

Class B.—Materials in this class include those to be used in structural assemblies for which a definite fire-resistance period is expected (Note). Test pieces 40 in. in length shall be taken from the samples as shown in Fig. 2 (*b*). Except in the case of sample pieces less than 2 ft. in length, 6 in. shall be cut from the ends of all sample pieces in preparing test specimens.

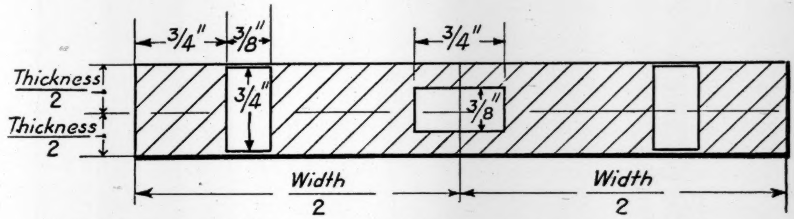
NOTE —*Example:* Fire-resistive doors and frames, partitions, column and beam protection, sash and frames.

Class C.—Materials in this class include those to be used without surfacing in situations where an average, rather than a specific minimum of treatment effect is desired (Note). Test specimens 40 in. in length shall be taken from the central portion of the sample piece, equal lengths being removed from each end of the sample to reduce to the proper length for test specimens. (See Fig. 2 (*c*)).

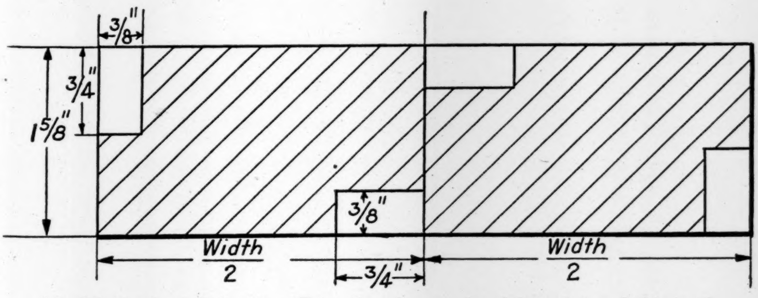
NOTE.—*Examples:* Scaffold plank, hoist towers, construction falsework, arch centering, etc.



(*a*) Method of Selecting Test Specimens for Materials of Class A.



(*b*) Method of Selecting Test Specimens for Materials of Class B.



(*c*) Method of Selecting Test Specimens for Materials of Class C.

FIG. 2.—Preparation of Test Specimens.

(*b*) Test specimens shall be $\frac{3}{8}$ by $\frac{3}{4}$ in. in cross-section and shall be dressed or lightly sanded to a smooth surface. After cutting they shall be conditioned to constant weight under a uniform relative humidity of 30 per cent and a temperature of 80° F.

(*c*) When test specimens are prepared from samples of irregular shape, they shall be selected in such a fashion as to secure a corresponding relation of the test specimen to the whole piece as regards probable thoroughness of treatment.

PROCEDURE

5. *Testing.*—(*a*) The specimens shall be weighed and tested at once.

(*b*) The bunsen burner (see Fig. 1) shall be adjusted to give a blue flame 11 ± ½ in. in height, with a tall indistinct inner cone; a temperature of 1000° C. ± 25 C. at the hottest point of the flame, and 180° C. ± 5° C. at the center of the top of the tube. The test specimen shall be placed in position in the tube, using a small screw hook for its suspension, and the pointer shall then be balanced at 0 per cent on the chart. The burner shall then be placed with its top 1 in. below the bottom of the specimen and directly beneath it.

(*c*) The flame shall be removed after 4 minutes. The percentage loss of weight of the specimen, and the temperature at the top of the tube shall be read at 30-second intervals from beginning of the test until 2 minutes after flaming stops. The loss of weight at the time the flame goes out and the maximum temperature reached also shall be noted.

6. *Interpretation of Test Data.*—The temperatures at the top of the tube during the test shall be plotted on cross-section paper, using time in minutes as abscissae and temperatures at top of tube in degrees Centigrade as ordinates. A line shall also be drawn horizontally across the paper at the 180° C. level, representing the temperature at the top of the tube, with the burner but without the specimen. The area between the plotted time-temperature curve and the line so drawn shall be obtained by means of a planimeter or estimated by counting the squares included.

EXPLANATORY NOTES ON UTILITY OF TEST DATA

Tests of fire retardant treated wood as used or installed in its various practical service applications must be made before suitability for one or another use can be expressed in terms of data secured by the fire tube test. These notes are not proposed for incorporation in the text of the test method, as they do not pertain to selection or handling of test specimens or to design or manipulation of testing apparatus.

The following example, however, illustrates how results of a test conducted in accordance with the procedure could be utilized in writing specifications for fire retardant treated wood or in recording the results of comparative experiments on materials of different treatments or for different purposes.

Example.—The area above the 180° C. line, and below the curve of temperatures at the top of tube with a specimen under test, expressed in percentage of the area below the 180° C. line, shall not exceed the respective values tabulated below.

	AVERAGE OF ALL TEST SPECIMENS	LEAST RESISTANT SPECIMEN
Material of Class A.............	.... per cent	.... per cent
Material of Class B.............	.... per cent	.... per cent
Material of Class C.............	.... per cent	.... per cent

.... per cent of all specimens from Class A or C material shall cease flaming within 1 minute after burner is removed, and in no case shall the loss of weight in 6 minutes exceed .... per cent.

.... per cent of all specimens from material of Class B shall cease flaming within 1 minute after burner is removed, and in no case shall the loss of weight in 6 minutes exceed .... per cent.

REPORT OF COMMITTEE C-6

ON

DRAIN TILE

Committee C-6 held one meeting during the past year, in Detroit, Mich., on March 20, 1930. At this meeting the committee received reports of several researches, abstracts of which are presented below, considered several suggestions for revisions and extensions of the drain tile standards and transacted routine business.

The present membership of the committee is 19, of which 7 are classified as producers, 4 as consumers and 8 as general interests.

Brief abstracts of the reports of the investigations in progress follow:

IOWA ENGINEERING EXPERIMENT STATION

(By Anson Marston)

Studies at the Iowa Engineering Experiment Station, started more than 20 years ago, led to the discovery of the original theory of the loads upon pipe in ditches, $W = CwB^2$, as published in 1913.[1] A continuation of the studies made possible the extension of the general formula to loads upon rigid conduits projecting up into embankments and led to the discovery of the height of equal settlement, which shows the differences in load resulting from variations in the proportions of the conduit which project above the subgrade; this material was published in 1922. Later researches have resulted in the discovery and utilization of the settlement-deflection ratio, which indicates the variation in load due to the relative settlements of the top of the conduit and the material alongside, and which made possible the further extension of the general theory so that it now covers the whole range of conditions from complete ditch condition, through incomplete ditch and projection conditions to complete projection condition, and the whole range of conduits from rigid to flexible.

The studies have shown also the ratios of the supporting strengths developed by the pipe with the different test bearings, in the ditch with different bedding conditions, and in the embankment with ordinary projection bedding and a projection ratio of 0.90, and the distribution of pressures around conduits under different conditions. With a rigid conduit in a ditch, the pressures are very high at the top and bottom, and so small as to be negligible at the sides. With a rigid conduit in an embankment the pressures at the top and bottom are high, while those at the sides are small and in agreement with Rankine's theory. When a flexible pipe is laid in an embankment, the distribution of pressures for very low fills is similar to that for rigid pipe, but as the fill is raised and has opportunity for settlement, the pipe deforms, and the pressures tend to become more nearly uniform around the pipe.

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[1] "The Theory of Loads on Pipes in Ditches," *Bulletin No. 31*, Iowa State College Engineering Experiment Station, Ames, Iowa.

In addition to these studies of the loads due to the fill materials the work has shown the percentages of static and moving super-loads transmitted through the filling material to the conduit.

A more complete statement of these theories has been made in a paper presented before the meeting of the Advisory Board on Highway Research, Washington, D. C., December 12, 1929.[1]

(By W. J. Schlick)

During 1928 and 1929, the Iowa Engineering Experiment Station, in cooperation with the Clay Products Association, carried on a series of studies of the loads upon pipe in wide ditches with vertical sides and with sloping sides. These studies are not complete, but the results:

1. Verify the principle stated in 1913[2] that the load upon a pipe in a sloping-sided ditch is the same as that in a vertical-sided ditch of width equal to the width of the sloping-sided ditch at the level of the top of the pipe.
2. Indicate that, for rigid pipe, the ditch formula gives the correct load upon the pipe so long as the width of ditch does not exceed one and one-half times the breadth of the pipe; and that for widths of ditch three or more times the breadth of the pipe the projection formula should be used.
3. Indicate that for widths of ditch between one and one-half and three times the breadth of the pipe the decision between the formulas is influenced by the settlement-deflection ratio and the ratio of the height of fill to the breadth of the pipe.

U. S. BUREAU OF PUBLIC ROADS

(By D. G. Miller)

The U. S. Bureau of Public Roads in cooperation with the Department of Agriculture, University of Minnesota and the Department of Drainage and Waters, State of Minnesota, has continued the investigations at University Farm, St. Paul, Minn., relative to the durability of drain tile under exposure to various soil conditions.

The work of the laboratory for the past two years has been substantially along the same lines as reported to Committee C-6 in 1926[3] and 1927[4] although considerably more time than heretofore has been devoted to studies of the deterioration of concrete subjected to the action of peat soils. In this work there have been made to date 12,250 cylinders representing 50 different types of concrete. Cylinders of each type of concrete have been installed in three different peats and one mineral soil in both Minnesota and Wisconsin, making a total of eight installations. Plans provide for examinations and tests of cylinders at intervals of 1, 3 and 5 years and longer if the earlier tests indicate the desirability. The first of the 5-year tests were made in the summer of

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[1] "The Theory of External Loads on Closed Conduits in the Light of the Latest Experiments," *Bulletin No. 96*, Iowa State College Engineering Experiment Station, Ames, Iowa.

[2] "The Theory of Loads on Pipes in Ditches," *Bulletin No. 31*, Iowa State College Engineering Experiment Station, Ames, Iowa.

[3] *Proceedings*, Am. Soc. Testing Materials, Vol. 26, Part I, p. 234 (1926).

[4] *Proceedings*, Am. Soc. Testing Materials, Vol. 27, Part I, p. 319 (1927).

1929. The tests so far indicate that concrete of poor quality will not withstand the action of even those peats relatively low in acidity. Definite information as to the relative durability of the different types of the better concretes under the various exposure conditions is not yet conclusive enough to be of value.

The effect of steam curing of concrete at temperatures up to 350° F. for a wide range of time periods has been studied in considerable detail with reference to the development of resistance to the action of sulfate waters, and several interesting developments have resulted. Much of the time for the past year has been devoted to gathering together the loose ends of the concrete-alkali work preparatory to the completion of a report dealing with this phase of the work to date. The later results are given in a paper presented at this annual meeting of the Society.[1]

Considerable work has been done towards correlating so far as possible results of absorption tests and frost resistance of clay tile used in Minnesota, this work perhaps more properly falling under the classification of service than research.

Technical Bulletin No. 52 "Experimental and Mathematical Analyses of Drain Tile Testing and New Test Bearing," based on the work of the laboratory, became available early in 1929 through publication by the University of Minnesota Agricultural Experiment Station.

PORTLAND CEMENT ASSOCIATION

(By D. A. Abrams)

A comprehensive series of field tests of portland-cement concrete exposed to sulfate soils and waters was begun by the Portland Cement Association in 1921. About 2000 concrete cylinders, 10 in. in diameter and 24 in. in length, were made in the Chicago laboratory, and at ages of 2 to 3 months were placed in sulfate soils and waters at Montrose, Colo., and Medicine Lake, S. Dak. These sites were selected as offering the most severe conditions to be found, and could not readily be improved upon as sites for accelerated tests. Attack may be attributed in part to frost action, the temperature at each of the sites being extremely low in winter.

The specimens covered the widest range in quality of concrete (lean to rich mixtures, wet to dry consistencies, poorly-graded to well-graded aggregates, etc.), so that many failures at an early date were to be expected.

Eight inspections have been made after exposures of 6 months, 1, 1½, 2, 3, 4, 5 and 7 years; the 7-year inspection was made during the summer of 1928. From these inspections the following conclusions can be drawn:

1. An intimate relation was found between the 28-day strength of plastic workable concretes and their ability to withstand sulfate attack; the stronger the concrete, the better it resisted sulfate attack. This relationship was found to be true for different proportions, consistencies, gradings of aggregates and curing conditions.

2. The results for the workable mixes show a very good correlation between water-cement ratio and both strength and alkali resistance.

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[1] D. G. Miller, "Strength and Resistance to Sulfate Waters of Concrete Cured in Water Vapor at Temperatures Between 100 and 350° F.," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 636 (1930).

3. Specimens of natural-cement concrete disintegrated after exposures of 6 to 12 months. The resistance of concretes made with portland cements was, in general, proportional to the amount of cement used.

4. Integral water and alkali proofing compounds in general gave poorer results than similar concrete without these compounds, both in strength tests and in resistance to sulfates.

5. Boiled linseed oil, and a proprietary compound largely composed of linseed oil, when used as surface coatings, applied hot, almost entirely prevented sulfate attack for all mixes up to 7 years' exposure. Asphalt, tar and pitch gave favorable results. However, in many instances the latter materials did not adhere sufficiently to the concrete to exclude the sulfates.

A more detailed report of these studies has been published in the Report of the Director of Research, Portland Cement Association, November, 1928. The next inspection of these cylinders will probably be made at the end of 10 years' exposure in 1931.

The following possible revisions of the Standard Specifications for Drain Tile (C 4 – 24) were suggested:

1. Inclusion of a requirement for rate of applying load in making strength tests.

2. Revision of the strength test requirements to provide a closer correlation between required test strengths and loads for specified depths of ditch.

3. Inclusion of standards and tests covering durability in acid and alkali soils.

4. Revision of the requirements for the lower three-edge bearing when testing large tile, and the inclusion of the "Minnesota" bearing (lower sand-bearing and upper three-edge bearing).

Informal discussion of these suggestions brought out the facts: (1) that any revisions of the specifications as an A.S.T.M. standard would also affect the specifications as an American Standard approved by the American Standards Association;[1] (2) that there was no general demand for the revisions; and (3) that some of these suggestions probably would be considered also by Committee C-4 on Clay and Cement-Concrete Pipe. Because of these facts it was considered best to defer action until several of them could be acted upon at one time, and in cooperation with Committee C-4 for questions affecting the standards of both committees.

It was suggested that because of the increased use of perforated corrugated metal pipe for airport drainage, it might be within the province of the committee to consider specifications for such pipe. Since no demand for such specifications had been received from either consumers or producers, no action was taken.

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[1] Committee C-6 also functions as the Sectional Committee on Specifications for Drain Tile under the procedure of the American Standards Association.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

An Advisory Committee, consisting of the chairman, the secretary, and the chairmen of Subcommittees I and II, was authorized.

Mr. P. H. Bates was designated to represent this committee on the Section on Effect of Speed of Testing, of Committee E-1 on Methods of Testing.

This report has been submitted to letter ballot of the committee, which consists of 19 members; 18 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

ANSON MARSTON,
Chairman.

W. J. SCHLICK,
Secretary.

REPORT OF COMMITTEE C-8
ON
REFRACTORIES

Committee C-8 held two meetings during the year subsequent to the annual meeting of the Society at Atlantic City in June, 1929. The first meeting was held in Columbus, Ohio, in September, at the time of the fall meeting of the American Refractories Institute, and the second in Toronto, Canada, in February, 1930, concurrently with the annual meeting of the American Ceramic Society.

Refractories Test Manual:

The committee has had a growing presentiment that the desired effectiveness in the use of refractory tests in the control of manufacture, inspection and utilization of refractories would not be attained until all tests procedures and methods of reporting data had been put upon a sound statistical basis. The Precision and Tolerances Section accordingly undertook this past year the preparation of what has been termed a "Manual for the Interpretation of Refractory Test Data." The procedures given in the manual have been based, in so far as possible, on well-established, modern statistical theory and the symbols and definitions are those which are being adopted quite generally in work of this kind. The manual has been written to meet the immediate needs of refractory engineers and other technologists in this field, with the understanding that from time to time it would be revised to keep pace with advances in theory and practice.

The committee has approved the publication of this manual as information and it accordingly appears in the Appendix to this report.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Proposed Revision of Tentative Standard.—As the result of suggestions from Committee E-8 on Nomenclature and Definitions the committee recommends the following revisions of the terms "spalling" and "pyrometric cone equivalent" appearing in the Tentative Definitions of Terms Relating to Refractories (C 71 – 28 T)[1] and, upon approval of these revisions, that the definitions be continued as tentative.

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[1] **_Proceedings_, Am. Soc. Testing Mats., Vol. 28, Part I, p. 858 (1928); also 1929 Book of A.S.T.M. Tentative Standards**, p. 248.

Spalling.—Change the definition of this term from its present form: namely,

> *Spalling.*—Breaking or cracking of refractories to such an extent that fragments are separated, presenting newly exposed surfaces of the residual mass.

to read as follows:

> *Spalling.*—In the case of refractories, the breaking or crushing of the unit due to thermal, mechanical or structural causes, presenting newly exposed surfaces of the residual mass.

Pyrometric Cone Equivalent (*P. C. E.*).—Change the definition of this term from its present form: namely,

> *Pyrometric Cone Equivalent* (*P. C. E.*).—An index to the degree of fusion resulting in a cone of the material bending until the tip touches the plaque as a result of a definite heat treatment, in accordance with the Standard Method of Test for Softening Point of Fire-Clay Brick (A.S.T.M. Designation: C 24) of the American Society for Testing Materials.

to read as follows:

> *Pyrometric Cone Equivalent* (*P. C. E.*).—In the case of refractories, the number of that standard cone whose tip would touch the supporting plaque simultaneously with a cone of the material being investigated when tested in accordance with the Standard Method of Test for Softening Point of Fire-Clay Brick (A.S.T.M. Designation: C 24) of the American Society for Testing Materials.

No change is recommended in the notes following these definitions.

The committee also recommends the following new definitions of terms relating to heat transmission of refractories, to be added to the Tentative Definitions of Terms Relating to Refractories (C 71 – 28 T):

HEAT TRANSMISSION TERMS

Thermal Conductivity.—The thermal conductivity of a homogeneous material is the rate of heat flow, under steady conditions, per unit area, and per unit temperature gradient, in the direction perpendicular to the area.

Thermal Resistivity.—Thermal resistivity is the reciprocal of thermal conductivity.

Resistance.—The resistance of a body between two iso-thermal surfaces is equal to the difference between the temperatures of the iso-thermal surfaces necessary to maintain unit rate of heat flow.

Conductance.—The conductance of a body between two iso-thermal surfaces is equal to the rate of heat flow through the body, per unit difference between the temperatures of the iso-thermal surfaces.

Film Resistance.—The film resistance at the boundary between a fluid and another medium in contact with it is equal to the differences between the temperature of the body of the fluid and that of the medium in contact with it, necessary to maintain unit rate of heat flow.

Surface Coefficient.—The surface coefficient at the boundary between a fluid and another medium in contact with it is equal to the rate of heat flow through the film per unit area of contact surface and unit difference between the temperature of the main body of the fluid and that of the medium in contact with it.

Total Resistance.—The total resistance to heat flow is the sum of the individual resistances through which the heat flows in series, from one medium to another.

Transmittance.—The transmittance of a system in which heat flows from one medium to another through one or more intermediate resistances, is equal to the rate of heat flow from one medium to the other divided by the difference in the temperature of the two media.

Transmission.—The transmission is the net rate of the heat flow from one medium to another, for conditions under consideration regardless of kind of transfer.

HEAT TRANSMISSION SYMBOLS

	SYMBOL
Area (normal to the path of heat flow)	A
Temperature, deg. Fahr. or deg. Cent.	t
Temperature, deg. Fahr. absolute or deg. K. (deg. Cent. absolute)	T
Length of path of heat flow (thickness)	L
Total quantity of heat transferred	Q
Thermal transmission (heat transferred per unit time)	q
Thermal conductivity	k

Proposed Tentative Revision of Standard.—The committee recommends as a tentative revision that the title of the Standard Method of Test for Softening Point of Fire-Clay Brick (C 24 – 28)[1] be changed to read as follows, by the addition of the italicized words and the omission of those in brackets:

> Standard Method of Test for [Softening Point] *Determining the Pyrometric Cone Equivalent* of Fire-Clay *and Fire* Brick.

This revision in title is being recommended for two reasons: (1) The test is no longer limited in its usage to fire-clay brick but is applied to testing raw clays and numerous other fired refractories and (2) the term "softening point" is gradually being superseded in all the committee's standards by "pyrometric cone equivalent" which it is felt is a more accurate and descriptive term.

Tentative Standard Continued as Tentative.—Since further changes are contemplated in the method of conducting the spalling test, the committee recommends that the Tentative Method of Test for Resistance of Fire-Clay Brick to Thermal Spalling Action (C 38 – 27 T) be continued as tentative without revision for another year.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 89.

The recommendations appearing in this report affecting standards and tentative standards have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF TENTATIVE STANDARD			
Definitions of Terms Relating to Refractories (C 71 - 28 T):			
Revision of Terms Spalling and Pyrometric Cone Equivalent	24	0	3
Terms and Symbols Relating to Heat Transmission	26	0	1
II. TENTATIVE REVISION OF STANDARD			
Method of Test for Softening Point of Fire-Clay Brick (C 24 - 28)	24	3	0

RESEARCH ACTIVITIES OF SUBCOMMITTEES

Standard Fire-Clay Samples.—In view of the rather widespread practice of indicating definite chemical composition in specifications pertaining to purchase of fire clay and fire-clay refractories and to the use of chemical analysis on this type of material in plant control work, the committee has felt the necessity of standard samples of fire clay. Accordingly, the committee arranged with the U. S. Bureau of Standards to have prepared standard samples of (*a*) raw plastic fire clay and (*b*) raw flint fire clay. A number of representative producers, consumers and consultants cooperated in establishing the composition of these clays. The cooperating groups are as follows:

American Refractories Institute Fellowship
Corhart Refractories Co.
General Refractories Co.
Harbison-Walker Refractories Co.
Baltimore and Ohio Railroad Co.
Carnegie Steel Co.
Mr. Dana Demorest, Ohio State University
Mariner & Hoskins
Pittsburgh Testing Laboratory
Mr. M. H. Thornberry, Missouri School of Mines.

Abrasion at High Temperature.—Mr. J. B. Shaw of Pennsylvania State College, who has been carrying on an investigation for the development of a suitable test method for determining the resistance of refractories to abrasion at high temperature, reported considerable progress with his work this year. A method has been developed which consists essentially of moving by means of a jack-hammer, a blunt water-cooled chisel point back and forth across the face of the heated brick. The chisel has a rounded point $\frac{1}{8}$ in. in radius and 1 in. in width. Eleven brick are tested at one time in a suitable furnace.

To date, fire-clay brick manufactured by the hand-made, stiff-mud and dry-press processes and of hard, medium and soft burn, as well as standard silica, magnesite and chrome refractories, have been tested with the method. All specimens were tested cold, and at temperatures of 1000° C. and 1350° C.

The data obtained so far indicate the test has promise.

Cold Crushing of Fire-Clay Brick.—At the suggestion of the committee and with the approval of the Advisory Council of the Engineering Experiment Station of the Ohio State University, Mr. H. K. Mitra of the latter organization, investigated the crushing strength of fire-clay brick in three directions, namely, flat, on edge and endwise, with the idea of developing data to be used in making recommendations for a standard cold crushing test. Fire-clay refractories made by three common methods, hand-made, stiff-mud, and dry-press processes, were tested. Data of this type for building and other brick have been existent in the literature but it was felt that these data were not necessarily applicable to refractories because of differences in the manner of manufacture and burning.

In addition to determining the cold crushing strength, the flexual strength and porosity were also determined. It was thought that possibly some relation existed between these various properties and that it might be possible to translate the values obtained for cold crushing (flatwise) into values for the other directions (on end and edgewise), or to translate flat crushing into flexual strength data and possibly to find some correlation to porosity.

The data obtained did not show any simple mathematical relationship between the various properties of the brick.

It was found that end crushing gave most consistent results.

Slag Resistance of Refractories.—At the Toronto meeting of the committee a representative of the Special Committee on Boiler Refractories of the American Society of Mechanical Engineers was invited to be present to describe a test for determining slag resistance which is being investigated by the A.S.M.E. at the U. S. Bureau of Standards' Station at Columbus, Ohio. The test appears to give very reliable data and is based on a determination of the mineralogical phases which develop at certain temperatures when the refractory and slag in question are heated and then quenched. In addition to the accuracy of the test, it appeals in not requiring very extensive apparatus. The specimens of refractory are very small, and are drilled with a $\frac{1}{4}$-in. hole which is filled with slag in preparation for testing. The heating of the refractory is carried out in a small quenching furnace such as is generally part of the equipment of petrographic laboratories. Thin sections of the refractory-slag interface are subsequently made and then examined with a petrographic microscope.

Investigation of the P. C. E. Test.—The Section on Temperature has carried on a very active investigation of the uniformity and dependability of P. C. E. results obtained with several types of P. C. E. furnaces at nine different laboratories. The section also collected data on the physical condition of standard pyrometric cones as now supplied to the trade. It has further given some consideration to the question of the adoption of a standard temperature scale corresponding to the various cones.

Three types of furnaces based on the heating agency were studied in the investigation, namely, air-gas, oxygen-acetylene, and gran-annular carbon resistance. Eleven different refractory materials were tested in all cooperating laboratories. Analysis of the data from the tests yielded results tending to indicate that the gran-annular carbon resistance furnace showed most promise of being eventually recommended as a standard furnace.

The survey of the condition of standard pyrometric cones as now shipped to the trade, showed that they varied in size and shape and other miscellaneous features to such an extent that the committee concluded corrective measures were desirable.

The trend of opinion of the committee regarding a standard temperature scale corresponding to standard pyrometric cones, is toward the temperature scale published by C. O. Fairchild and M. F. Peters, "Characteristics of Pyrometric Cones."[1]

The election of officers resulted in the selection of G. A. Bole, chairman; E. H. Van Schoick, vice-chairman; and L. J. Trostel, secretary for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 31 members; 30 members returned their ballots, of whom 29 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

G. A. BOLE,
Chairman.

L. J. TROSTEL,
Secretary.

EDITORIAL NOTE

The proposed revision of the terms "spalling" and "pyrometric cone equivalent" appearing in the Tentative Definitions of Terms Relating to Refractories and the addition of terms and symbols relating to heat transmission were accepted for publication as tentative. The definitions in their revised form appear on page 1037.

The proposed tentative revision of the Standard Method of Test for Softening Point of Fire-Clay Brick was accepted for publication as tentative and appears on page 1275.

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[1] *Journal*, Am. Ceramic Society, Vol. 9, No. 11, pp. 701 to 743, Nov. (1926).

APPENDIX

MANUAL FOR INTERPRETATION OF REFRACTORY TEST DATA (1929)

This Manual for Interpretation of Refractory Test Data (1929) was prepared by the Subcommittee on Precision and Tolerance consisting of Messrs. J. Spotts McDowell and A. E. R. Westman. It was the opinion of the subcommittee that the desired effectiveness in the use of refractory tests in the control of manufacture, inspection, and utilization of refractories would not be attained until all test procedures and methods of reporting data had been put upon a sound statistical basis. The preparation of this manual was considered to be the first step in this direction.

The procedures given in the manual have been based, in so far as possible, on well-established, modern statistical theory, and the symbols and definitions are those which are being adopted quite generally in work of this kind. However, a completely satisfactory answer to some of the questions which the investigator of refractories might raise could not be given because both adequate theory and data were lacking. In such cases, the subcommittee has given what appears to it to be the most satisfactory answer at the present time. This was done because it was considered desirable to meet the immediate needs of the refractory engineer, with the understanding that from time to time the manual would be revised to keep pace with advances in theory and practice. The date "1929" has been incorporated in the title of the manual so that the investigator may specify exactly the methods he has used in analyzing and reporting data.

Acknowledgments.—The subcommittee wishes to acknowledge the ready cooperation of W. A. Shewhart, of the Bell Telephone Laboratories. Acknowledgment is also due the Ceramic Department, Rutgers University, and the Ontario Research Foundation for their cooperation.

INTRODUCTION

1. *Uses of Data on Refractories.*—Manufacturers, consumers, and independent research organizations make a very large number of tests of refractory bricks and materials each year. The data so obtained may enable one: (1) to set standards of quality, (2) to determine when these standards are met or (3) to find laws of relationship between properties. Their usefulness for these purposes would be greatly increased if (*a*) the sampling of the products or materials were performed in accordance with correct principles, (*b*) the tests were made by standard methods, where available, and (*c*) the data were reported so as to have only one meaning and to contain in the space available as much information as possible about the sampling conditions, test methods, and the results of the tests.

2. *Purpose of Manual.*—The standardization of test methods for refractories has been in progress for some time. Four standard and two tentative methods are listed in the current List of Standards of the A.S.T.M. (given below), and two other test methods are described in standard specifications. The methods of sampling, ways of reporting data and the determination of the precision of results, however, have not received as much attention as they deserve. It is the purposes of this manual to discuss these phases of the testing of refractories and to give methods which, if generally followed, should increase greatly the usefulness of data on refractories.

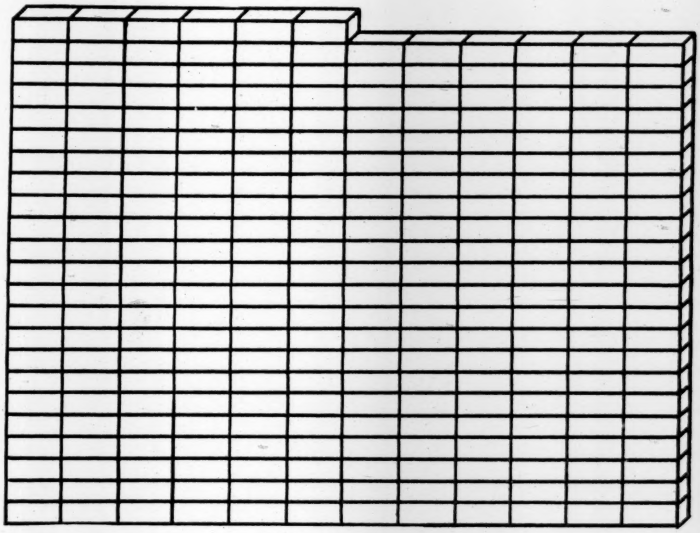


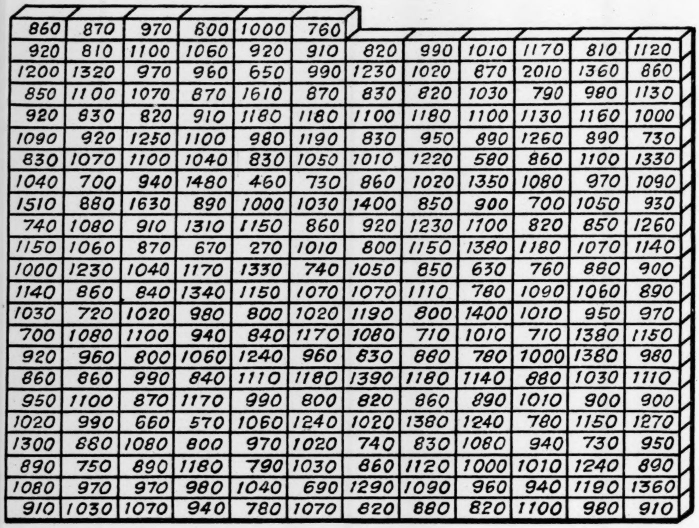
FIG. 1.—Pile of 270 Bricks of a Typical Brand.

IMPORTANCE OF SAMPLING AND METHODS OF REPORTING DATA

3. *Sampling.*—In order to show why methods of sampling have to be considered in connection with refractory tests, let us consider the pile of 270 bricks of a typical brand shown in Fig. 1, and suppose that we wish to obtain information regarding the strengths of these bricks.

If we select any one brick from the pile, we can measure its strength by following the procedure given in the Society's Tentative Methods of Testing Brick (Compression, Flexure and Absorption) (C 67 – 28 T.) We then know the strength of that brick quite accurately. If we were to test another brick, however, we should find quite probably that its strength was different from that of the first brick. In fact, if we marked each brick with a number giving its transverse strength in pounds per square inch, the pile of bricks would have the appearance shown in Fig. 2.

An examination of this figure will show that if we rely on measurements of only one brick the value obtained for the strength of the brand will depend to a large extent on the brick that is chosen for test. For this reason it is customary to determine the strengths of a number of bricks. If the strengths of all the bricks were determined, we should have complete information. However, such a procedure is impractical when we are trying to determine the strength of a brand of bricks which may be manufactured at the rate of 50,000 per day.



860	870	970	600	1000	760						
920	810	1100	1060	920	910	820	990	1010	1170	810	1120
1200	1320	970	960	650	990	1230	1020	870	2010	1360	860
850	1100	1070	870	1610	870	830	820	1030	790	980	1130
920	830	820	910	1180	1180	1100	1180	1100	1130	1160	1000
1090	920	1250	1100	980	1190	830	950	890	1260	890	730
830	1070	1100	1040	830	1050	1010	1220	580	860	1100	1330
1040	700	940	1480	460	730	860	1020	1350	1080	970	1090
1510	880	1630	890	1000	1030	1400	850	900	700	1050	930
740	1080	910	1310	1150	860	920	1230	1100	820	850	1260
1150	1060	870	670	270	1010	800	1150	1380	1180	1070	1140
1000	1230	1040	1170	1330	740	1050	850	630	760	880	900
1140	860	840	1340	1150	1070	1070	1110	780	1090	1060	890
1030	720	1020	980	800	1020	1190	800	1400	1010	950	970
700	1080	1100	940	840	1170	1080	710	1010	710	1380	1150
920	960	800	1060	1240	960	830	880	780	1000	1380	980
860	860	990	840	1110	1180	1390	1180	1140	880	1030	1110
950	1100	870	1170	990	800	820	860	890	1010	900	900
1020	990	660	570	1060	1240	1020	1380	1240	780	1150	1270
1300	880	1080	800	970	1020	740	830	1080	940	730	950
890	750	890	1180	790	1030	860	1120	1000	1010	1240	890
1080	970	970	980	1040	690	1290	1090	960	940	1190	1360
910	1030	1070	940	780	1070	820	880	820	1100	980	910

FIG. 2.—Same as Fig. 1, with Bricks Numbered Giving Transverse Strength in pounds per square inch.

It is necessary, therefore, to select a *sample* which consists of more than one brick and yet includes only a small percentage of the total number of bricks in which we are interested. The extent to which the data obtained from measurements of the sample are representative of the brand in question will depend on (1) how the sample is selected and (2) how many bricks are included in the sample. In other words, problems in *sampling* must be faced.

4. *Reporting Data.*—After a sufficiently large and representative sample has been selected and tested, there remains the problem of

calculating from the usually large mass of data so obtained a few values which will contain as much as possible of the information given by the data. There is also the problem of determining, as best we can, how successfully the sampling has been performed. It is at this point that adequate methods of analyzing and reporting data are necessary.

The methods of analyzing and reporting which are the most desirable from the scientific point of view and which should be used in preparing data for publication lack the simplicity which is essential in some kinds of plant-control work or in making reports to executives. For this reason, a description of simple methods which are satisfactory for such inspection purposes will be given and will be followed by a description of methods for establishing standards for materials which should be used for publication purposes.

HOW TO ANALYZE AND REPORT DATA FOR INSPECTION PURPOSES

5. *Procedure.*—Leaving sampling problems for consideration later, let us suppose that the first fifteen bricks shown in Fig. 2 constitute a representative sample of some brand. It is out of the question to report all fifteen values, both from lack of space and from the inability of the reader to grasp the significance of fifteen values. For inspection purposes, the "arithmetic mean" and the "average deviation" of the values should be calculated and reported.

6. *Arithmetic Mean.*—To find the arithmetic mean of a series of numbers, such as the fifteen transverse strength values shown in the second column of Table I, all the values are added together and divided by the number of values. Thus, in Table I the arithmetic mean is obtained by dividing the sum of the fifteen strength values (14,980), by their number (15) and is equal to 998.67 lb. per sq. in.

7. *Average Deviation.*—To find the average deviation of a series of numbers the difference is found between each number and the arithmetic mean of the series, all the differences or deviations are added together, neglecting their signs, and divided by their number. Thus, in Table I the differences between the values and their arithmetic mean are listed in the third column, their sum is 2341.3 lb. per sq. in., and the average deviation is 162.09 lb. per. sq. in.

8. *Physical Significance.*—If twenty bricks of varying thickness whose arithmetic mean thickness is $2\frac{1}{2}$ in. are piled in a single stack, the stack will have the same height as that formed of twenty bricks exactly $2\frac{1}{2}$ in. in thickness. If the average deviation of the thickness of the bricks is $\frac{1}{4}$ in., the total amount of grinding or building up necessary to make each brick $2\frac{1}{2}$ in. thick is 5 in. ($20 \times \frac{1}{4}$ in.).

If two brands of brick differ in strength and uniformity of strength, then, in general, the arithmetic mean strength of the stronger brand will be greater than that of the weaker, and the less uniform brand will have the greater average deviation. In general, too, more reliance may be placed on the arithmetic mean of a series of values when their average deviation is small.

For smaller samples, the use of the *average deviation* instead of the *standard deviation* (to be described later) results in a loss of about 20 per cent of the information contained in the raw data, so far as the estimation of errors is concerned, and can be justified on the ground of simplicity only.

TABLE I.—CALCULATION OF ARITHMETIC MEAN AND AVERAGE DEVIATION.

BRICK	TRANSVERSE STRENGTH, LB. PER SQ. IN.	DEVIATION, LB. PER SQ. IN.
No. 1	860	138.7
No. 2	920	78.7
No. 3	1 200	201.3
No. 4	850	148.7
No. 5	920	78.7
No. 6	1 090	91.3
No. 7	830	168.7
No. 8	1 040	41.3
No. 9	1 510	511.3
No. 10	740	258.7
No. 11	1 150	151.3
No. 12	1 000	1.3
No. 13	1 140	141.3
No. 14	1 030	31.3
No. 15	700	298.7
	14 980	2341.3

$$\text{Arithmetic Mean} = \frac{14\ 980}{15} = 998.67 \text{ lb. per sq. in.}$$

$$\text{Average Deviation} = \frac{2341.3}{15} = 162.09 \text{ lb. per sq. in.}$$

9. *Form of Calculation and Report.*—The number of figures or places which should be carried in calculating the arithmetic mean and average deviation and in reporting their values for inspection purposes deserves consideration. In making the calculations it is much better to carry too many rather than too few figures. With calculating machines and tables generally available, the extra labor involved is not large and loss of accuracy in the calculations is avoided. The use of two or three more places than the accuracy of the measurements seemed to justify received such condemnation in texts written

when rapid-calculating machines and tables were not available that many engineers were led to believe that the carrying of extra figures resulted in inaccurate results. This is not the case. In general, if the experimental values are accurate to three places, at least four places should be used in calculating the arithmetic mean and average deviation.

When arithmetic means and average deviations are used in certain types of reports, especially those to non-technical executives, accuracy is not the only consideration and care must be taken lest a misleading conception of high accuracy be given by the use of too many figures. For instance, if the arithmetic mean strengths of two brands of bricks are reported as 1056 and 1063 lb. per sq. in., a purchasing agent might give preference to the second brand, although the difference of 7 lb. per sq. in. might have no practical significance. If the arithmetic mean values 1056 and 1063 lb. per sq. in. were accurate to only 10 lb. per sq. in., it would be better to report them both as 1060 lb. per sq. in. For general inspection purposes the value of the average deviation should be reported to one significant figure and the corresponding arithmetic mean should be rounded off to the same number of decimal places. The use of this rule is illustrated in Table II.

TABLE II.—REPORTING DATA FOR INSPECTION PURPOSES.

Calculated		Reported	
Arithmetic Mean	Average Deviation	Arithmetic Mean	Average Deviation
1763.57	± 0.435	1763.6	± 0.4
1763.57	± 4.35	1764	± 4
1763.57	± 43.5	1760	± 40
1763.57	± 435	1800	± 400

An inspection report, then, should have the following form, in which the values from Table I are used for illustration:

	Transverse Strength, lb. per sq. in.			
Name of Brand	Arithmetic Mean	Average Deviation	Number of Specimens	Date
	1000	± 200	15	September 20, 1929

TEST METHOD: A.S.T.M. C 67 – 28 T.
CALCULATION METHOD: A.S.T.M. Manual for Interpretation of Refractory Test Data (1929).

HOW TO ANALYZE AND REPORT DATA FOR SCIENTIFIC PURPOSES

10. *Useful Functions.*—Assuming again that the first fifteen bricks in Fig. 2 constitute a random sample of a brand, our problem from the scientific point of view is that of expressing as much as possi-

ble of the information in the raw data by means of a few numbers. It may be shown that for our purposes two easily defined functions of the data contain all essential information. These two functions are the "arithmetic mean" and the "standard deviation." They have a practical significance which may be understood readily so that replacement of the fifteen individual values by their arithmetic mean and standard deviation saves space and promotes understanding with practically no loss of information. The definitions and methods of calculation of the arithmetic mean and standard deviation will now be given, the strengths of fifteen bricks which are listed in the second column of Table III being used to illustrate the calculations.

11. *Arithmetic Mean.*—The arithmetic mean of a series of values n in number, may be obtained by dividing the sum of the values by n. Thus the sum of the fifteen values in the second column of Table III is 14,980, the number of values (or n) is 15, and the arithmetic mean is 14,980 ÷ 15 = 998.76 lb. per sq. in. If the n values are represented by the symbols, $X_1, X_2, X_3 \ldots\ldots X_n$, and the arithmetic mean by $\overline{X}$, then the definition can be stated mathematically as follows:

$$\text{Arithmetic mean} = \overline{X} = \frac{X_1 + X_2 + X_3 \ldots\ldots + X_n}{n} = \frac{\Sigma X_i}{n} \ldots\ldots\ldots\ldots\ldots (1)$$

12. *Standard Deviation.*—The standard deviation of a series of values n in number may be obtained by dividing the sum of the *squares* of the values by n, subtracting the *square* of the arithmetic mean and then taking the square root. The symbol σ is used almost universally to represent the standard deviation. Using the other symbols defined in the previous paragraph, the standard deviation may be defined mathematically as follows:

$$\text{Standard deviation}^{a} = \sigma = \sqrt{\frac{X_1^2 + X_2^2 + X_3^2 \ldots\ldots X_n^2}{n} - \overline{X}^2} = \sqrt{\frac{\Sigma X_i^2}{n} - \overline{X}^2} \ldots\ldots (2)$$

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[a] This formula is frequently expressed as follows:

$$\sigma = \sqrt{\frac{\Sigma(\overline{X} - X_i)^2}{n}} = \sqrt{\frac{\Sigma(di)^2}{n}},$$ where d represents the deviation of an observation from the arithmetic mean. The formula may be verbally expressed thus: Obtain the sum of the squares of the deviations from the mean of all the observations in the series (Σd^2). Divide this sum by the number of observations, and extract the square root.

The method of calculation is illustrated in Table III. The table of squares and square roots which is appended hereto can be used in such calculations.

13. *Physical Significance.*—The arithmetic mean, $\overline{X}$, and the standard deviation σ, of the 270 transverse strength values shown in Fig. 2 are approximately 1000 lb. per sq. in. and 200 lb. per sq. in., respectively. To show the physical significnce of these functions, let us suppose that a scale of transverse strength, divided at 100 lb per sq. in. intervals, is laid on the ground, and that the bricks are piled on the scale in accordance with their strengths. Thus, bricks having strengths between 550 and 650 lb. per sq. in. are piled above the 600 lb. per sq. in. mark, and so forth. The result will be a pile of bricks with the appearance shown in Fig. 3. The arithmetic mean, $\overline{X} = 1000$, is shown in the figure and a range equal to the standard deviation, $\sigma = 200$, marked off on either side at A and B. The range from A to B is commonly written: $\overline{X} \pm \sigma$, or (in this case) 1000 ± 200. It will be noticed that the pile of bricks centers around the arithmetic mean which thus indicates the central tendency. In either direction from the arithmetic mean the stacks of bricks rapidly lose height. It will also be noticed that somewhat more than half the bricks fall within 200 lb. per sq. in. of the arithmetic mean, or in the range $\overline{X} \pm \sigma$. The standard deviation, σ, is a measure of the spread of the pile. A com-

TABLE III.—CALCULATION OF ARITHMETIC MEAN AND STANDARD DEVIATION.

BRICK	TRANSVERSE STRENGTH, X, LB. PER SQ. IN.	SQUARE OF TRANSVERSE STRENGTH, X^2
No. 1	860	739 600
No. 2	920	846 400
No. 3	1 200	1 440 000
No. 4	850	722 500
No. 5	920	846 400
No. 6	1 090	1 188 100
No. 7	830	688 900
No. 8	1 040	1 081 600
No. 9	1 510	2 280 100
No. 10	740	547 600
No. 11	1 150	1 322 500
No. 12	1 000	1 000 000
No. 13	1 140	1 299 600
No. 14	1 030	1 060 900
No. 15	700	490 000
$n = 15$	14 980	15 554 200

$$\text{Arithmetic Mean} = \overline{X} = \frac{14\,980}{15} = 998.67 \text{ lb. per sq. in.}$$

$$\text{Standard Deviation}^{a} = \sigma = \sqrt{\frac{15\,554\,200}{15} - (998.67)^2} = 199.01 \text{ lb. per sq. in.}$$

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[a] The symbol σ is used almost universally to represent the standard deviation. Where its use is inconvenient, it may be replaced by the letters "S.D."

parison of Fig. 3 with Fig. 2 will show that Fig. 3 gives a much more definite idea of the strength and uniformity of the bricks than does Fig. 2. If σ and $\overline{X}$ are given, a close approximation of Fig. 3 can be calculated.

14. *Form of Calculation and Report.*—The principles which determine the number of places to be carried in calculations were given in Section 9. In calculating values of $\overline{X}$ and σ from experimental data accurate to three figures, at least four, and preferably five, places should be used in calculating $\overline{X}$ and at least seven, and preferably eight, places in the squares from which σ is calculated.

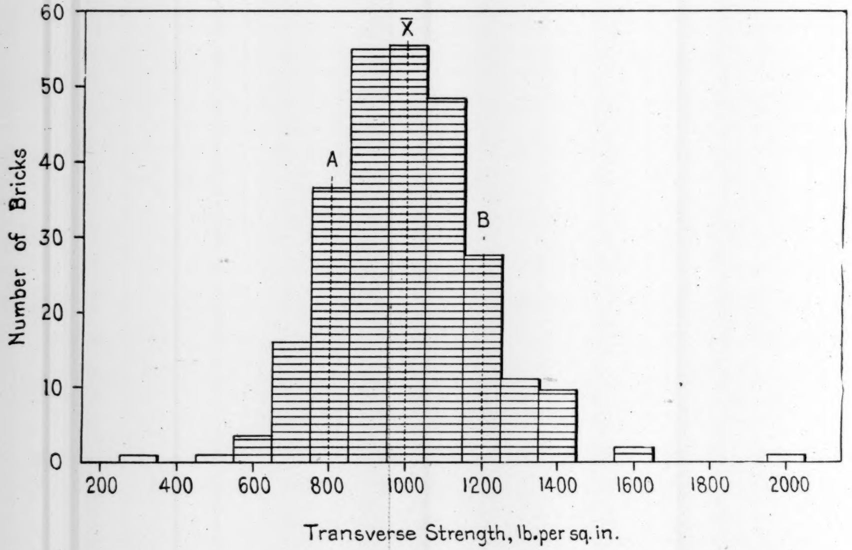

FIG. 3.—Bricks Piled in Accordance with Their Strengths.

When values of $\overline{X}$ and σ are to be published in technical literature or used in further statistical work, σ should be reported to two, and preferably three, significant figures, and $\overline{X}$ should be rounded off to the same number of decimal places. Thus, if the last significant figure in the value of σ represents 1 lb. per sq. in., $\overline{X}$ should be reported to 1 lb. per sq. in. The values calculated in Table III may be rounded off as follows:

CALCULATED	REPORTED
σ = 199.01 lb. per sq. in.	199 lb. per sq. in.
$\overline{X}$ = 998.67 lb. per sq. in.	999 lb. per sq. in.

When both $\overline{X}$ and σ are reported in a scientific paper, no harm is done if more places are given, as the value of σ shows the accuracy of $\overline{X}$, and false conceptions of accuracy are avoided.

For scientific purposes, then, the values of $\overline{X}$ and σ, calculated in Table III, should be reported as follows:

	TRANSVERSE STRENGTH, LB. PER SQ. IN.			
NAME OF BRAND	ARITHMETIC MEAN ($\overline{X}$)	STANDARD DEVIATION (σ)	NUMBER OF SPECIMENS, n	DATE
	999	199	15	September 20, 1929

TEST METHOD: A.S.T.M. C 67 - 28 T.

CALCULATION METHOD: A.S.T.M. Manual for Interpretation of Refractory Test Data (1929).

15. *Precision of Test Method.*—In our discussion of the data given in Figs. 2 and 3, we have attributed all the lack of agreement to variability of the bricks. However, if the bricks had been absolutely uniform, some lack of agreement would still have been found, due to unavoidable errors in making the tests. If the test method had been absolutely precise, the value of σ would have been smaller and due solely to the variability of the bricks. In the case we were considering, the errors of the test method were relatively small and for most purposes their effect could be neglected. For very accurate work, however, and when relatively inaccurate tests are performed on uniform materials, the precision of the test method is a matter of importance. In such cases the standard deviation of the values that would be obtained by repeatedly testing one specimen, or by testing a practically uniform material, should be determined and reported as σ_E. Methods for determining values of σ_E and for using them in correcting values of σ, etc., are beyond the scope of this manual but may be found readily in the literature.[1]

TABLE IV.

RANGE ARITHMETIC MEAN, PLUS OR MINUS	MINIMUM PERCENTAGE OF VALUES LYING WITHIN RANGE
2σ	75.0 per cent
3σ	88.9 "
4σ	93.8 "
4.47σ	95.0 "
5σ	96.0 "
6σ	97.2 "

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[1] W. A. Shewhart, "Correction of Data for Errors of Measurement," *The Bell System Technical Journal*, Vol. V, January, 1926, p. 11; also A. E. R. Westman, "The Relative Importance of Errors of Sampling and Measurement in Ceramic Research," *Journal*, Am. Ceramic Soc., 11, 4, p. 264 (1928).

INTERPRETATION OF DATA

16. *Interpretation of Data.*—The following questions are commonly asked in connection with data on refractories: (1) How close was the agreement between the values from which the arithmetic mean was calculated? (2) How accurate is the arithmetic mean? (3) What is the variability of the material? (4) Should any of the individual values be rejected? The following paragraphs will show how the arithmetic mean and standard deviation can be used in finding an answer to these questions.

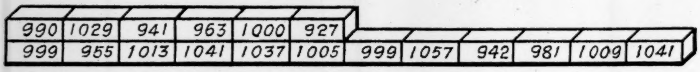

FIG. 4.—Bricks Representing the Mean-Strength of the 18 Groups of 15 Bricks.

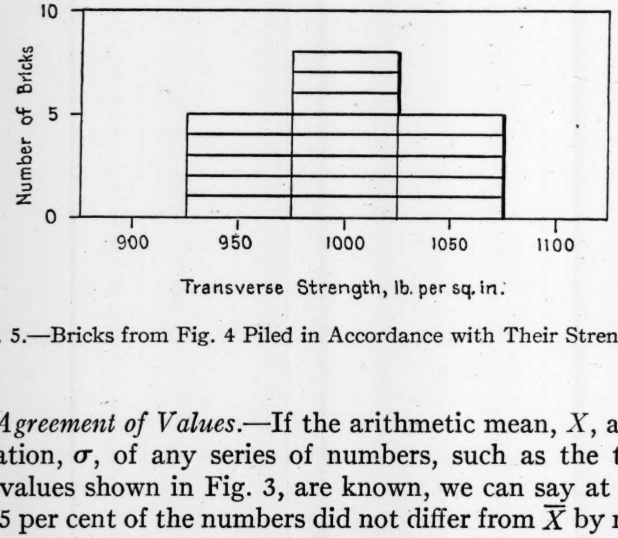

FIG. 5.—Bricks from Fig. 4 Piled in Accordance with Their Strengths.

17. *Agreement of Values.*—If the arithmetic mean, X, and standard deviation, σ, of any series of numbers, such as the transverse strength values shown in Fig. 3, are known, we can say at once that at least 75 per cent of the numbers did not differ from $\overline{X}$ by more than 2σ, that at least 88.9 per cent of the numbers did not differ from $\overline{X}$ by more than 3σ, etc. Thus, at least 75 per cent of the 15 values in Fig. 3 fall within the range 800 to 1198 lb. per sq. in. The minimum percentage of the individual values included in a range of 2σ, 3σ, 4σ, etc., on either side of the arithmetic mean is given in Table IV.

18. *Accuracy of Arithmetic Mean.*—In Sections 3 and 4 it was pointed out that the strength of a brand based on tests of one brick will depend on the brick that is chosen for test. In the same way,

but to a less extent, the arithmetic-mean strength based on tests of n bricks will depend on which group of n bricks are chosen for test. For illustration, let us suppose that the 270 bricks shown in Figs. 2 and 3 are divided into groups of fifteen, and that the arithmetic-mean strength of each group is determined and marked on a brick. If the 18 numbered bricks so obtained were stacked at random, the pile would have the appearance shown in Fig. 4.

If the bricks were stacked in accordance with the scheme shown in Fig. 3, they would appear as in Fig. 5.

Our object in making tests such as those reported in Table III is usually to find what might be called the "true transverse strength" of the brand. In the absence of a better estimate we use the arithmetic mean of the observed strengths as an estimate of the true strength of the brand. If we were sure that the variation in strengths found was due only to a constant system of chance causes, that is, that no assignable causes of variation were present (such as the inclusion of some bag-wall brick), we could calculate the range on either side of the true mean strength within which a given percentage of arithmetic means similar to that under discussion may be expected to fall. Unfortunately, with most tests on refractories not enough work has been done to entirely justify this procedure. However, having the information given by $\overline{X}$ and σ, and needing an immediate estimate of the accuracy of $\overline{X}$, we have to assume that the foregoing conditions hold.

On this assumption, the range on either side of the true mean value, within which 50 per cent, 68.3 per cent, and 95 per cent of similarly obtained arithmetic means may be expected to fall, is given in Table V. Thus, about 95 per cent of arithmetic means obtained from samples of 15 similar to that listed in Fig. 3 may be expected to fall within $0.543 \times 199 = 108.1$ lb. per sq. in. of the true mean strength of the brand, or in the range, 999 ± 108 lb. per sq. in., using our value of $\overline{X}$ as an estimate of the true mean strength.

19. *Variability of Product.*—If n bricks of a certain brand have been tested, the "coefficient of variation" for that brand can be calculated by means of the relation:

$$\text{Coefficient of Variation} = \frac{100\sigma}{\overline{X}}\sqrt{\frac{n}{n-2}}$$

where σ is the standard deviation, $\overline{X}$ the arithmetic mean and n the number of specimens in the sample.

Thus, the coefficient of variation of the strength of the bricks can be calculated from the data in Table III as follows:

$$\text{Coefficient of Variation} = \frac{100 \times 199.01}{998.67}\sqrt{\frac{15}{15-2}}$$

$$\text{“} \quad \text{“} \quad \text{“} \quad = 21.4$$

A comparison of the variability of two brands with respect to some property can be secured by determining their coefficients of variation. The more variable brand will, in general, have a larger coefficient.

TABLE V.

Number of Specimens in Samples, n	Ranges Within Which Indicated Percentages of Arithmetic Means May Be Expected		
	50 per cent	68.3 per cent	95 per cent
3	$\pm 0.674\ \sigma^a$	$\pm 1.00\ \sigma^a$	$\pm 1.96\ \sigma^a$
4	$0.477\ \sigma$	$0.707\ \sigma$	$1.39\ \sigma$
5	$0.389\ \sigma$	$0.577\ \sigma$	$1.13\ \sigma$
6	$0.337\ \sigma$	$0.500\ \sigma$	$0.980\ \sigma$
7	$0.302\ \sigma$	$0.448\ \sigma$	$0.878\ \sigma$
8	$0.275\ \sigma$	$0.408\ \sigma$	$0.800\ \sigma$
9	$0.255\ \sigma$	$0.378\ \sigma$	$0.741\ \sigma$
10	$0.233\ \sigma$	$0.345\ \sigma$	$0.676\ \sigma$
11	$0.225\ \sigma$	$0.333\ \sigma$	$0.653\ \sigma$
12	$0.213\ \sigma$	$0.316\ \sigma$	$0.619\ \sigma$
13	$0.203\ \sigma$	$0.301\ \sigma$	$0.590\ \sigma$
14	$0.195\ \sigma$	$0.289\ \sigma$	$0.566\ \sigma$
15	$0.187\ \sigma$	$0.277\ \sigma$	$0.543\ \sigma$
16	$0.180\ \sigma$	$0.267\ \sigma$	$0.523\ \sigma$
17	$0.174\ \sigma$	$0.258\ \sigma$	$0.506\ \sigma$
18	$0.169\ \sigma$	$0.250\ \sigma$	$0.490\ \sigma$
19	$0.163\ \sigma$	$0.242\ \sigma$	$0.474\ \sigma$
20	$0.159\ \sigma$	$0.236\ \sigma$	$0.463\ \sigma$
21	$0.155\ \sigma$	$0.229\ \sigma$	$0.449\ \sigma$
22	$0.151\ \sigma$	$0.224\ \sigma$	$0.439\ \sigma$
23	$0.147\ \sigma$	$0.218\ \sigma$	$0.427\ \sigma$
24	$0.144\ \sigma$	$0.213\ \sigma$	$0.417\ \sigma$
25	$0.140\ \sigma$	$0.208\ \sigma$	$0.408\ \sigma$
26	$0.138\ \sigma$	$0.204\ \sigma$	$0.400\ \sigma$
27	$0.135\ \sigma$	$0.200\ \sigma$	$0.392\ \sigma$
28	$0.132\ \sigma$	$0.196\ \sigma$	$0.384\ \sigma$
29	$0.130\ \sigma$	$0.192\ \sigma$	$0.376\ \sigma$
30	$0.127\ \sigma$	$0.189\ \sigma$	$0.370\ \sigma$

[a] σ = Standard Deviation calculated from one sample of n specimens.

20. *Rejection of Values.*—It occasionally happens in testing refractories that one or two individual values will differ greatly from the others. An example is shown in Fig. 3, the brick to the extreme right being very much stronger and that to the extreme left very much weaker than the general run of bricks. It is occasionally argued that the strength values for such bricks should be disregarded in calculating an arithmetic mean because we are interested primarily in the majority of the bricks and do not wish a few bricks, which may have been given severe burning treatment or have escaped culling, to exert an undue influence on the results of our calculations.

The appearance of such exceptional values is a very strong indication that the methods of sampling and testing are not sufficiently specified or have not been effectively applied, with the result that some factors which should have been controlled have been left to chance. A rigorous revision of the sampling and testing specifications is indicated, therefore, the purpose being to avoid the occurrence of exceptional values in the future.

When an immediate decision must be based on data in which exceptional values occur, the specimens and records should be examined to see if some physical reason for the values can be discovered, which will justify their rejection. Such revision should not be confined to the exceptional values only.

If values are rejected on the sole ground that they are exceptional, the arithmetic mean calculated both before and after such rejection should be reported.

CORRELATION OF DATA

21. *Correlation Coefficient.*—It occasionally happens in the testing of refractories that we wish to determine the degree of relationship between two properties, such as transverse strength and porosity of a particular brand. Although a full discussion of such problems is beyond the scope of the present manual, it may be worth while to point out that a third statistical function, the "correlation coefficient," may be used. This function is designated by the symbol r and is defined mathematically as follows:

$$\text{Correlation Coefficient} = r = \frac{\frac{\Sigma XY}{n} - \bar{X}\,\bar{Y}}{\sigma \quad \sigma_Y} \dots\dots\dots\dots\dots (3)$$

where n is the number of specimens in the sample, X represents the values of one property, Y represents the values of the other property, X_1Y_1 is the product of the X and Y values for the first specimen, ΣXY is the sum of all such products, $\bar{X}$ is the arithmetic mean of the X values, $\bar{Y}$ is the arithmetic mean of the Y values, σ_X is the standard deviation of the X values, and σ_Y is the standard deviation of the Y values.

When the relationship between two properties is linear, a correlation coefficient of unity indicates absolute linear dependence; a coefficient of zero shows complete independence; intermediate values of the coefficient indicate partial dependence and can be used in predicting the value of one property when that of the other is known.

For a particular case, the greater the value of the coefficient, the higher will be the accuracy of prediction.

SELECTION OF SAMPLES

22. *Sampling Theory.*—Although sampling procedure is usually given little attention, the methods used in sampling are as important, if not more important, than those used in analyzing and reporting data. The calculated values can never be better than the sample.

In spite of the fact that many papers on sampling have been written,[1] it is still true that each sampling problem is to a large extent a problem in itself and requires the expenditure of thought and ingenuity on the part of the investigator. The main problems of sampling are being investigated by the Technical Committee on Presentation of Data, of Committee E-1 on Methods of Testing, and it may be possible to present a rigorous treatment of the subject in a later edition of this manual. With the help of statistical methods, it is frequently possible to eliminate assignable causes of variation in the properties of a product. When this has been done, sampling is a comparatively simple problem and the methods of analyzing data which have been given are strictly applicable.

TABLE VI.—CLASSIFICATION OF SAMPLING PROBLEMS.

As to Materials	As to Property Tested	As to Purpose of Tests	As to Information Required
Bricks and shapes.	**Not influenced by degree of firing.**	Specification.	Size of Sample.
Bulk materials.	**Influenced by degree of firing.**	Control.	Sampling procedure.
		Research.	

The following discussion of sampling problems has been included in this manual to meet the immediate needs of the investigator of refractories, pending the development of a more rigorous treatment of the subject.

23. *Common Cases.*—Sampling problems which arise frequently in testing refractories can be classified conveniently in accordance with (1) the nature of the material tested, (2) the property to be measured, (3) the purpose of the test, and (4) the sampling information required. Such a classification is shown in Table VI.

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[1] **W. J. Sharwood and M. von Bernewitz, "Bibliography of Literature on Sampling," Bureau of Mines *Reports of Investigations, Serial 2336*, 85 pages (1922). One thousand references and a list of patents are included.**

24. *General Principles Governing Procedure.*—All sampling procedures should be such that the following general requirements are met as nearly as possible:

1. Sample should be representative.
2. Assignable causes of variation should be eliminated.
3. Sample should be big enough, that is, include enough material or a sufficient number of specimens.
4. In doubtful cases, sampling should be checked by repetition.

The first requirement, namely, that the sample should be representative, means that in sampling bricks coming from a tunnel kiln, for instance, selection should not be restricted to the top layers on the cars, as these are usually fired to a higher temperature and do not represent the bulk of the product.

The second requirement, namely, the elimination of assignable causes of variation, is very important. As was pointed out in Section 18, the most useful and powerful statistical methods are strictly applicable only when this requirement is met. Every effort should be made, therefore, to leave nothing to chance which can be controlled. Statistical methods are of great help in this connection. It is particularly difficult to meet this requirement in sampling bricks at any stage of their manufacture after they have left the die or press because the final strength of a brick depends to a considerable extent upon the position it occupies in the drier and the kiln. As driers and kilns are improved, this difficulty will be eliminated gradually. At the present time, if well-burned and light-burned bricks can be distinguished, it would be better to sample each group separately. In general, when the data can be divided into groups within each of which the second requirement is met, such division should be made. Sampling in any group should be performed in such a way that the chance of selecting a brick or a specimen of a given value is as nearly as possible the same throughout the sampling operation. In all cases, the presence of any exceptional conditions should be recorded.

The third requirement, namely, a sufficiently large sample, is important, because, as shown in Section 18 and Table V, the accuracy of an average depends on the size of the sample, it being assumed that the first and second requirements are met. The problem of deciding what size of sample should be chosen for test will be discussed later.

The fourth requirement, namely, that in doubtful cases the adequacy of the procedure should be verified by repetition is frequently overlooked. If a sampling procedure is repeated three or four times under as nearly identical conditions as possible, the values of $\overline{X}$, σ, etc., calculated from the samples may be treated as individual values and analyzed as shown in Sections 10 to 15. Inability to secure reasonable checks by this method will indicate at once that the sampling procedure needs improvement.

25. *Sampling Bricks.*—Bricks are commonly sampled in order (1) to control and improve their manufacture, (2) to determine whether or not they meet the specifications under which they were purchased, or (3) for research purposes.

For the first purpose, namely, control of manufacture, the sampling procedure depends upon the property to be controlled. If it is not influenced appreciably by the drying and firing treatment, the best point of sampling is at the die or press. A certain proportion of the mix or the undried bricks should be by-passed continuously so that a representative gross sample is obtained. This may be reduced to a laboratory sample by standard methods. Control of such properties as P.C.E., chemical composition, etc., may be obtained in this way. If the property to be controlled is influenced considerably by the firing and drying treatment, samples should be taken after the bricks are fired. With tunnel kilns, this means sampling from the cars as they come from the kiln; with periodic kilns, samples should be taken when the kilns are drawn. When the kiln or car contains both hard and light-fired bricks, it is best to sample them separately, at the same time recording the proportion of light-fired brick in the kiln.

When bricks are sampled on account of purchase specification requirements, sampling should take place at the manufacturing plant, either as the bricks are loaded into the railroad cars or from lots in the shed awaiting approval before shipment. Sampling from hacks in the shed is sometimes necessary but should be avoided if possible. It is much better to sample the bricks as they are hacked.

26. *Number of Specimens.*—The usual purpose in sampling and testing refractories is to secure data from which an arithmetic mean can be calculated and used as an estimate of the true value for the brand. If the first and second sampling requirements in Section 23 are satisfied, the number of specimens which should be included in a sample depends on (1) the desired accuracy of the arithmetic mean, as expressed by such numbers as the 95-per-cent range given in Table V, and (2) the variability of the product under test. The first factor is determined by the use which is to be made of the arithmetic mean; the second factor can be determined only by actual tests of the product.

In order to show how previous tests of a product can be used as a guide in deciding the number of specimens to be used in further tests, let us consider the example given in Section 18. In this section it was shown that an arithmetic mean based on tests of 15 bricks had a 95-per-cent range of 108 lb. per sq. in. Suppose an arithmetic mean having a 95-per-cent range of 54 lb. per sq. in. is desired. Then the number of specimens required may be estimated as follows:

$$\text{Estimated number of specimens} = \frac{15 \times (108)^2}{(54)^2} = 60 \text{ specimens.}$$

The rule which was used in the foregoing calculation may be stated as follows: Multiply the number of specimens used in obtaining an arithmetic mean by the square of the 95-per-cent range of that mean and divide by the square of the 95-per-cent range required.

TABLE VII.—TABLE FOR PREDICTING 95-PER-CENT RANGES OF ARITHMETIC MEANS FOR FIRE-CLAY BRICK.

If the indicated tests and numbers of specimens are used to determine arithmetic mean values for a typical brand of fire brick, the 95-per-cent ranges of such values will ordinarily approximate those shown in the table.

Property	Method	Number of Specimens in Sample			
		4	16	25	49
Transverse Strength on Edge (lb. per sq. in.)	A.S.T.M. C 67 - 28 T	±192	96	76	55
Compressive Strength (lb. per sq. in.)	A.S.T.M. C 67 - 28 T	±640	320	256	180
Absorption (per cent)	A.S.T.M. C 67 - 28 T, Whole Bricks	±0.90	0.47	0.38	0.26
Porosity (per cent)	A.S.T.M. C 20 - 20, Whole Bricks, Mercury Balance	±1.85	0.93	0.73	0.52

Occasionally it happens that no previous test results are available from which estimates of sample size can be made. In such cases even a very rough estimate is a great help in planning a series of tests. Very few data have been reported in the literature in a form that allows such estimates to be made. It is hoped that this manual will enable this to be done in the future. In the meantime, estimates of sample size for some common tests have been calculated and are given in Table VII. Brands of brick which are less uniform in properties than the average brand will require larger samples than those listed in the table.

A good plan is to test the number of bricks shown in Table VII. If the desired accuracy is not secured, the results of the tests can be used in estimating the number of additional bricks to be tested. Up to the present time, the prevailing tendency has been to use too few specimens, although doubling the number of specimens seldom increases the total time needed for certain tests by more than about ten per cent.

27. *Sampling Bulk Materials.*—Relatively few bulk refractory materials are bought or sold on specification at the present time. However, the initial step in solving plant problems or in establishing plant control is often that of sampling the clays as they come from the mine or sampling the raw mix before it is formed into bricks.

The general principles of sampling apply equally well to bulk materials and to bricks. In the case of bricks, however, we are dealing with a number of units of uniform size and relatively uniform composition; whereas in the usual bulk materials we have a much larger number of units or particles which differ greatly in size and composition. In addition, it is frequently true that the smaller particles have a different composition from that of the larger particles. On the other hand, when we are dealing with bulk materials, it is possible to work with samples containing a very large number of particles or units, especially when the material is finely ground.

In sampling bulk materials the following general requirements, which were discussed in Section 24, should be kept in mind:

1. Sample should be representative.
2. Assignable causes of variation should be eliminated.
3. Sample should be big enough.
4. In doubtful cases sampling should be checked by repetition.

Requirement No. 1 means, in the case of bulk materials, that some method of continuously by-passing part of the mix or clay should be used. In sampling clay arriving in mine cars, it is better to take out an occasional whole car rather than sample from each car, as experience has shown that the latter procedure is very apt to give misleading results.

Requirement No. 2 means that the introduction of any exceptional material should be carefully avoided and every effort made to control all the factors which influence the final result.

The size of sample which will meet requirement No. 3 is determined by the fineness of the material, its uniformity of composition, the quantity to be sampled, and the precision desired, depending upon the purpose for which the tests are made.

LIST OF A.S.T.M. TEST METHODS, DEFINITIONS, AND SPECIFICATIONS RELATING TO REFRACTORIES

TEST METHODS

C 16 – 20.	Test for Refractory Materials Under Load at High Temperatures.
C 20 – 20.	Test for Porosity and Permanent Volume Changes in Refractory Materials.
C 24 – 28.	Test for Softening Point of Fire-Clay Brick.
C 18 – 21.	Ultimate Chemical Analysis of Refractory Materials, Including Chrome Ores and Chrome Brick.
C 67 – 28 T.	Testing Brick (Compression, Flexure, and Absorption).
C 38 – 27 T.	Test for Resistance of Fire-Clay Brick to Thermal Spalling Action.

DEFINITIONS

C 27 – 28.	Clay Refractories.
C 71 – 28	Terms Relating to Refractories.
C 71 – 28 T.	Terms Relating to Refractories.

SPECIFICATIONS

C 63 – 28	Clay Fire Brick for Malleable Furnace with Removable Bungs and for Annealing Ovens.
C 64 – 28	Clay Fire Brick for Stationary Boiler Service.
C 65 – 28	Clay Fire Brick for Marine Boiler Service.

SQUARES AND SQUARE ROOTS

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
			4.	16.	2.	**10**	100	3.1623	70	4 900	8.3666
			4.1	16.81	2.025	11	121	3.3166	71	5 041	8.4261
0.1	0.01	0.3162	4.2	17.64	2.049	12	144	3.4641	72	5 184	8.4853
0.15	0.0225	0.3873	4.3	18.49	2.074	13	169	3.6056	73	5 329	8.5440
0.2	0.04	0.4472	4.4	19.36	2.098	14	196	3.7417	74	5 476	8.6023
0.25	0.0625	0.500	4.5	20.25	2.121	15	225	3.8730	75	5 625	8.6603
0.3	0.09	0.5477	4.6	21.16	2.145	16	256	4.	76	5 776	8.7178
0.35	0.1225	0.5916	4.7	22.09	2.168	17	289	4.1231	77	5 929	8.7750
0.4	0.16	0.6325	4.8	23.04	2.191	18	324	4.2426	78	6 084	8.8318
0.45	0.2025	0.6708	4.9	24.01	2.214	19	361	4.3589	79	6 241	8.8882
0.5	0.25	0.7071	**5.**	25.	2.2361	20	400	4.4721	80	6 400	8.9443
0.55	0.3025	0.7416	5.1	26.01	2.258	21	441	4.5826	81	6 561	9.
0.6	0.36	0.7746	5.2	27.04	2.280	22	484	4.6904	82	6 724	9.0554
0.65	0.4225	0.8062	5.3	28.09	2.302	23	529	4.7958	83	6 889	9.1104
0.7	0.49	0.8367	5.4	29.16	2.324	24	576	4.8990	84	7 056	9.1652
0.75	0.5625	0.8660	5.5	30.25	2.345	25	625	5.	85	7 225	9.2195
0.8	0.64	0.8944	5.6	31.36	2.366	26	676	5.0990	86	7 396	9.2736
0.85	0.7225	0.9219	5.7	32.49	2.387	27	729	5.1962	87	7 569	9.3276
0.9	0.81	0.9487	5.8	33.64	2.408	28	784	5.2915	88	7 744	9.3808
0.95	0.9025	0.9747	5.9	34.81	2.429	29	841	5.3852	89	7 921	9.4340
1.	1.	1.	**6.**	36.	2.4495	30	900	5.4772	90	8 100	9.4868
1.05	1.1025	1.025	6.1	37.21	2.470	31	961	5 5678	91	8 281	9.5394
1.1	1.21	1.049	6.2	38.44	2.490	32	1 024	5.6569	92	8 464	9.5917
1.15	1.3225	1.072	6.3	39.69	2.510	33	1 089	5 7446	93	8 649	9.6437
1.2	1.44	1.095	6.4	40.96	2.530	34	1 156	5.8310	94	8 836	9.6954
1.25	1.5625	1.118	6.5	42.25	2.550	35	1 225	5.9161	95	9 025	9.7468
1.3	1.69	1.140	6.6	43.56	2.569	36	1 296	6.	96	9 216	9.7980
1.35	1.8225	1.162	6.7	44.89	2.588	37	1 369	6.0828	97	9 409	9.8489
1.4	1.96	1.183	6.8	46.24	2.608	38	1 444	6.1644	98	9 604	9.8995
1.45	2.1025	1.204	6.9	47.61	2.627	39	1 521	6.2450	99	9 801	9.9499
1.5	2.25	1.2247	**7.**	49.	2.6458	40	1 600	6.3246	100	10 000	10.
1.55	2.4025	1.245	7.1	50.41	2.665	41	1 681	6.4031	101	10 201	10.0499
1.6	2.56	1.265	7.2	51.84	2.683	42	1 764	6.4807	102	10 404	10.0995
1.65	2.7225	1.285	7.3	53.29	2.702	43	1 849	6.5574	103	10 609	10.1489
1.7	2.89	1.304	7.4	54 76	2.720	44	1 936	6.6332	104	10 816	10.1980
1.75	3.0625	1.323	7.5	56.25	2.739	45	2 025	6.7082	105	11 025	10.2470
1.8	3.24	1.342	7.6	57.76	2.757	46	2 116	6.7823	106	11 236	10.2956
1.85	3.4225	1.360	7.7	59.29	2.775	47	2 209	6.8557	107	11 449	10.3441
1.9	3.61	1.378	7.8	60.84	2.793	48	2 304	6.9282	108	11 664	10.3923
1.95	3.8025	1.396	7.9	62.41	2.811	49	2 401	7.	109	11 881	10.4403
2.	4.	1.4142	**8.**	64.	2.8284	50	2 500	7.0711	110	12 100	10.4881
2.1	4.41	1.449	8.1	65.61	2.846	51	2 601	7.1414	111	12 321	10.5357
2.2	4.84	1.483	8.2	67.24	2.864	52	2 704	7.2111	112	12 544	10.5830
2.3	5.29	1.517	8.3	68.89	2.881	53	2 809	7.2801	113	12 769	10.6301
2.4	5.76	1.549	8.4	70.56	2.898	54	2 916	7.3485	114	12 996	10.6771
2.5	6.25	1.581	8.5	72.25	2.915	55	3 025	7.4162	115	13 225	10.7238
2.6	6.76	1.612	8.6	73.96	2.933	56	3 136	7.4833	116	13 456	10.7703
2.7	7.29	1.643	8.7	75.69	2.950	57	3 249	7.5498	117	13 689	10.8167
2.8	7.84	1.673	8.8	77.44	2.966	58	3 364	7.6158	118	13 924	10.8628
2 9	8.41	1.703	8.9	79.21	2.983	59	3 481	7.6811	119	14 161	10.9087
3	9.	1.7321	**9.**	81.	3.	60	3 600	7.7460	120	14 400	10.9545
3.1	9.61	1.761	9.1	82.81	3.017	61	3 721	7.8102	121	14 641	11.0000
3.2	10.24	1.789	9.2	84.64	3.033	62	3 844	7.8740	122	14 884	11.0454
3.3	10.89	1.817	9.3	86.49	3.050	63	3 969	7.9373	123	15 129	11.0905
3.4	11.56	1.844	9.4	88.36	3.066	64	4 096	8.	124	15 376	11.1355
3.5	12.25	1 871	9.5	90.25	3.082	65	4 225	8.0623	125	15 625	11.1803
3.6	12 96	1.897	9.6	92.16	3.098	66	4 356	8 1240	126	15 876	11.2250
3.7	13.69	1.924	9.7	94.09	3.114	67	4 489	8 1854	127	16 129	11.2694
3.8	14 44	1.949	9.8	96.04	3.130	68	4 624	8.2462	128	16 384	11.3137
3.9	15 21	1.975	9.9	98.01	3.146	69	4 761	8.3066	129	16 641	11.3578

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
130	16 900	11.4018	195	38 025	13.9642	260	67 600	16.1245	325	105 625	18.0278
131	17 161	11.4455	196	38 416	14.0000	261	68 121	16.1555	326	106 276	18.0555
132	17 424	11.4891	197	38 809	14.0357	262	68 644	16.1864	327	106 929	18.0831
133	17 689	11.5326	198	39 204	14.0712	263	69 169	16.2173	328	107 584	18.1108
134	17 956	11.5758	199	39 601	14.1067	264	69 696	16.2481	329	108 241	18.1384
135	18 225	11.6190	200	40 000	14.1421	265	70 225	16.2788	330	108 900	18.1659
136	18 496	11.6619	201	40 401	14.1774	266	70 756	16.3095	331	109 561	18.1934
137	18 769	11.7047	202	40 804	14.2127	267	71 289	16.3401	332	110 224	18.2209
138	19 044	11.7473	203	41 209	14.2478	268	71 824	16.3707	333	110 889	18.2483
139	19 321	11.7898	204	41 616	14.2829	269	72 361	16.4012	334	111 556	18.2757
140	19 600	11.8322	205	42 025	14.3178	270	72 900	16.4317	335	112 225	18.3030
141	19 881	11.8743	206	42 436	14.3527	271	73 441	16.4621	336	112 896	18.3303
142	20 164	11.9164	207	42 849	14.3875	272	73 984	16.4924	337	113 569	18.3576
143	20 449	11.9583	208	43 264	14.4222	273	74 529	16.5227	338	114 244	18.3848
144	20 736	12.0000	209	43 681	14.4568	274	75 076	16.5529	339	114 921	18.4120
145	21 025	12.0416	210	44 100	14.4914	275	75 625	16.5831	340	115 600	18.4391
146	21 316	12.0830	211	44 521	14.5258	276	76 176	16.6132	341	116 281	18.4662
147	21 609	12.1244	212	44 944	14.5602	277	76 729	16.6433	342	116 964	18.4932
148	21 904	12.1655	213	45 369	14.5945	278	77 284	16.6733	343	117 649	18.5203
149	22 201	12.2066	214	45 796	14.6287	279	77 841	16.7033	344	118 336	18.5472
150	22 500	12.2474	215	46 225	14.6629	280	78 400	16.7332	345	119 025	18.5742
151	22 801	12.2882	216	46 656	14.6969	281	78 961	16.7631	346	119 716	18.6011
152	23 104	12.3288	217	47 089	14.7309	282	79 524	16.7929	347	120 409	18.6279
153	23 409	12.3693	218	47 524	14.7648	283	80 089	16.8226	348	121 104	18.6548
154	23 716	12.4097	219	47 961	14.7986	284	80 656	16.8523	349	121 801	18.6815
155	24 025	12.4499	220	48 400	14.8324	285	81 225	16.8819	350	122 500	18.7083
156	24 336	12.4900	221	48 841	14.8661	286	81 796	16.9115	351	123 201	18.7350
157	24 649	12.5300	222	49 284	14.8997	287	82 369	16.9411	352	123 904	18.7617
158	24 964	12.5698	223	49 729	14.9332	288	82 944	16.9706	353	124 609	18.7883
159	25 281	12.6095	224	50 176	14.9666	289	83 521	17.0000	354	125 316	18.8149
160	25 600	12.6491	225	50 625	15.0000	290	84 100	17.0294	355	126 025	18.8414
161	25 921	12.6886	226	51 076	15.0333	291	84 681	17.0587	356	126 736	18.8680
162	26 244	12.7279	227	51 529	15.0665	292	85 264	17.0880	357	127 449	18.8944
163	26 569	12.7671	228	51 984	15.0997	293	85 849	17.1172	358	128 164	18.9209
164	26 896	12.8062	229	52 441	15.1327	294	86 436	17.1464	359	128 881	18.9473
165	27 225	12.8452	230	52 900	15.1658	295	87 025	17.1756	360	129 600	18.9737
166	27 556	12.8841	231	53 361	15.1987	296	87 616	17.2047	361	130 321	19.0000
167	27 889	12.9228	232	53 824	15.2315	297	88 209	17.2337	362	131 044	19.0263
168	28 224	12.9615	233	54 289	15.2643	298	88 804	17.2627	363	131 769	19.0526
169	28 561	13.0000	234	54 756	15.2971	299	89 401	17.2916	364	132 496	19.0788
170	28 900	13.0384	235	55 225	15.3297	300	90 000	17.3205	365	133 225	19.1050
171	29 241	13.0767	236	55 696	15.3623	301	90 601	17.3494	366	133 956	19.1311
172	29 584	13.1149	237	56 169	15.3948	302	91 204	17.3781	367	134 689	19.1572
173	29 929	13.1529	238	56 644	15.4272	303	91 809	17.4069	368	135 424	19.1833
174	30 276	13.1909	239	57 121	15.4596	304	92 416	17.4356	369	136 161	19.2094
175	30 625	13.2288	240	57 600	15.4919	305	93 025	17.4642	370	136 900	19.2354
176	30 976	13.2665	241	58 081	15.5242	306	93 636	17.4929	371	137 641	19.2614
177	31 329	13.3041	242	58 564	15.5563	307	94 249	17.5214	372	138 384	19.2873
178	31 684	13.3417	243	59 049	15.5885	308	94 864	17.5499	373	139 129	19.3132
179	32 041	13.3791	244	59 536	15.6205	309	95 481	17.5784	374	139 876	19.3391
180	32 400	13.4164	245	60 025	15.6525	310	96 100	17.6068	375	140 625	19.3649
181	32 761	13.4536	246	60 516	15.6844	311	96 721	17.6352	376	141 376	19.3907
182	33 124	13.4907	247	61 009	15.7162	312	97 344	17.6635	377	142 129	19.4165
183	33 489	13.5277	248	61 504	15.7480	313	97 969	17.6918	378	142 884	19.4422
184	33 856	13.5647	249	62 001	15.7797	314	98 596	17.7200	379	143 641	19.4679
185	34 225	13.6015	250	62 500	15.8114	315	99 225	17.7482	380	144 400	19.4936
186	34 596	13.6382	251	63 001	15.8430	316	99 856	17.7764	381	145 161	19.5192
187	34 969	13 6748	252	63 504	15.8745	317	100 489	17.8045	382	145 924	19.5448
188	35 344	13.7113	253	64 009	15.9060	318	101 124	17.8326	383	146 689	19.5704
189	35 721	13.7477	254	64 516	15.9374	319	101 761	17.8606	384	147 456	19.5959
190	36 100	13.7840	255	65 025	15.9687	320	102 400	17.8885	385	148 225	19.6214
191	36 481	13.8203	256	65 536	16.0000	321	103 041	17.9165	386	148 996	19.6469
192	36 864	13.8564	257	66 049	16.0312	322	103 684	17.9444	387	149 769	19.6723
193	37 249	13.8924	258	66 564	16.0624	323	104 329	17.9722	388	150 544	19.6977
194	37 636	13.9284	259	67 081	16.0935	324	104 976	18.0000	389	151 321	19.7231

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
390	152 100	19.7484	455	207 025	21.3307	520	270 400	22.8035	585	342 225	24.1868
391	152 881	19.7737	456	207 936	21.3542	521	271 441	22.8254	586	343 396	24.2074
392	153 664	19.7990	457	208 849	21.3776	522	272 484	22.8473	587	344 569	24.2281
393	154 449	19.8242	458	209 764	21.4009	523	273 529	22.8692	588	345 744	24.2487
394	155 236	19.8494	459	210 681	21.4243	524	274 576	22.8910	589	346 921	24.2693
395	156 025	19.8746	460	211 600	21.4476	525	275 625	22.9129	590	348 100	24.2899
396	156 816	19.8997	461	212 521	21.4709	526	276 676	22.9347	591	349 281	24.3105
397	157 609	19.9249	462	213 444	21.4942	527	277 729	22.9565	592	350 464	24.3311
398	158 404	19.9499	463	214 369	21.5174	528	278 784	22.9783	593	351 649	24.3516
399	159 201	19.9750	464	215 296	21.5407	529	279 841	23.0000	594	352 836	24.3721
400	160 000	20.0000	465	216 225	21.5639	530	280 900	23.0217	595	354 025	24.3926
401	160 801	20.0250	466	217 156	21.5870	531	281 961	23.0434	596	355 216	24.4131
402	161 604	20.0499	467	218 089	21.6102	532	283 024	23.0651	597	356 409	24.4336
403	162 409	20.0749	468	219 024	21.6333	533	284 089	23.0868	598	357 604	24.4540
404	163 216	20.0998	469	219 961	21.6564	534	285 156	23.1084	599	358 801	24.4745
405	164 025	20.1246	470	220 900	21.6795	535	286 225	23.1301	600	360 000	24.4949
406	164 836	20.1494	471	221 841	21.7025	536	287 296	23.1517	601	361 201	24.5153
407	165 649	20.1742	472	222 784	21.7256	537	288 369	23.1733	602	362 404	24.5357
408	166 464	20.1990	473	223 729	21.7486	538	289 444	23.1948	603	363 609	24.5561
409	167 281	20.2237	474	224 676	21.7715	539	290 521	23.2164	604	364 816	24.5764
410	168 100	20.2485	475	225 625	21.7945	540	291 600	23.2379	605	366 025	24.5967
411	168 921	20.2731	476	226 576	21.8174	541	292 681	23.2594	606	367 236	24.6171
412	169 744	20.2978	477	227 529	21.8403	542	293 764	23.2809	607	368 449	24.6374
413	170 569	20.3224	478	228 484	21.8632	543	294 849	23.3024	608	369 664	24.6577
414	171 396	20.3470	479	229 441	21.8861	544	295 936	23.3238	609	370 881	24.6779
415	172 225	20.3715	480	230 400	21.9089	545	297 025	23.3452	610	372 100	24.6982
416	173 056	20.3961	481	231 361	21.9317	546	298 116	23.3666	611	373 321	24.7184
417	173 889	20.4206	482	232 324	21.9545	547	299 209	23.3880	612	374 544	24.7386
418	174 724	20.4450	483	233 289	21.9773	548	300 304	23.4094	613	375 769	24.7588
419	175 561	20.4695	484	234 256	22.0000	549	301 401	23.4307	614	376 996	24.7790
420	176 400	20.4939	485	235 225	22.0227	550	302 500	23.4521	615	378 225	24.7992
421	177 241	20.5183	486	236 196	22.0454	551	303 601	23.4734	616	379 456	24.8193
422	178 084	20.5426	487	237 169	22.0681	552	304 704	23.4947	617	380 689	24.8395
423	178 929	20.5670	488	238 144	22.0907	553	305 809	23.5160	618	381 924	24.8596
424	179 776	20.5913	489	239 121	22.1133	554	306 916	23.5372	619	383 161	24.8797
425	180 625	20.6155	490	240 100	22.1359	555	308 025	23.5584	620	384 400	24.8998
426	181 476	20.6398	491	241 081	22.1585	556	309 136	23.5797	621	385 641	24.9199
427	182 329	20.6640	492	242 064	22.1811	557	310 249	23.6008	622	386 884	24.9399
428	183 184	20.6882	493	243 049	22.2036	558	311 364	23.6220	623	388 129	24.9600
429	184 041	20.7123	494	244 036	22.2261	559	312 481	23.6432	624	389 376	24.9800
430	184 900	20.7364	495	245 025	22.2486	560	313 600	23.6643	625	390 625	25.0000
431	185 761	20.7605	496	246 016	22.2711	561	314 721	23.6854	626	391 876	25.0200
432	186 624	20.7846	497	247 009	22.2935	562	315 844	23.7065	627	393 129	25.0400
433	187 489	20.8087	498	248 004	22.3159	563	316 969	23.7276	628	394 384	25.0599
434	188 356	20.8327	499	249 001	22.3383	564	318 096	23.7487	629	395 641	25.0799
435	189 225	20.8567	500	250 000	22.3607	565	319 225	23.7697	630	396 900	25.0998
436	190 096	20.8806	501	251 001	22.3830	566	320 356	23.7908	631	398 161	25.1197
437	190 969	20.9045	502	252 004	22.4054	567	321 489	23.8118	632	399 424	25.1396
438	191 844	20.9284	503	253 009	22.4277	568	322 624	23.8328	633	400 689	25.1595
439	192 721	20.9523	504	254 016	22.4499	569	323 761	23.8537	634	401 956	25.1794
440	193 600	20.9762	505	255 025	22.4722	570	324 900	23.8747	635	403 225	25.1992
441	194 481	21.0000	506	256 036	22.4944	571	326 041	23.8956	636	404 496	25.2190
442	195 364	21.0238	507	257 049	22.5167	572	327 184	23.9165	637	405 769	25.2389
443	196 249	21.0476	508	258 064	22.5389	573	328 329	23.9374	638	407 044	25.2587
444	197 136	21.0713	509	259 081	22.5610	574	329 476	23.9583	639	408 321	25.2784
445	198 025	21.0950	510	260 100	22.5832	575	330 625	23.9792	640	409 600	25.2982
446	198 916	21.1187	511	261 121	22.6053	576	331 776	24.0000	641	410 881	25.3180
447	199 809	21.1424	512	262 144	22.6274	577	332 929	24.0208	642	412 164	25.3377
448	200 704	21.1660	513	263 169	22.6495	578	334 084	24.0416	643	413 449	25.3574
449	201 601	21.1896	514	264 196	22.6716	579	335 241	24.0624	644	414 736	25.3772
450	202 500	21.2132	515	265 225	22.6936	580	336 400	24.0832	645	416 025	25.3969
451	203 401	21.2368	516	266 256	22.7156	581	337 561	24.1039	646	417 316	25.4165
452	204 304	21.2603	517	267 289	22.7376	582	338 724	24.1247	647	418 609	25.4362
453	205 209	21.2838	518	268 324	22.7596	583	339 889	24.1454	648	419 904	25.4558
454	206 116	21.3073	519	269 361	22.7816	584	341 056	24.1661	649	421 201	25.4755

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
650	422 500	25.4951	715	511 225	26.7395	780	608 400	27.9285	845	714 025	29.0689
651	423 801	25.5147	716	512 656	26.7582	781	609 961	27.9464	846	715 716	29.0861
652	425 104	25.5343	717	514 089	26.7769	782	611 524	27.9643	847	717 409	29.1033
653	426 409	25.5539	718	515 524	26.7955	783	613 089	27.9821	848	719 104	29.1204
654	427 716	25.5734	719	516 961	26.8142	784	614 656	28.0000	849	720 801	29.1376
655	429 025	25.5930	720	518 400	26.8328	785	616 225	28.0179	850	722 500	29.1548
656	430 336	25.6125	721	519 841	26.8514	786	617 796	28.0357	851	724 201	29.1719
657	431 649	25.6320	722	521 284	26.8701	787	619 369	28.0535	852	725 904	29.1890
658	432 964	25.6515	723	522 729	26.8887	788	620 944	28.0713	853	727 609	29.2062
659	434 281	25.6710	724	524 176	26.9072	789	622 521	28.0891	854	729 316	29.2233
660	435 600	25.6905	725	525 625	26.9258	790	624 100	28.1069	855	731 025	29.2404
661	436 921	25.7099	726	527 076	26.9444	791	625 681	28.1247	856	732 736	29.2575
662	438 244	25.7294	727	528 529	26.9629	792	627 264	28.1425	857	734 449	29.2746
663	439 569	25.7488	728	529 984	26.9815	793	628 849	28.1603	858	736 164	29.2916
664	440 896	25.7682	729	531 441	27.0000	794	630 436	28.1780	859	737 881	29.3087
665	442 225	25.7876	730	532 900	27.0185	795	632 025	28.1957	860	739 600	29.3258
666	443 556	25.8070	731	534 361	27.0370	796	633 616	28.2135	861	741 321	29.3428
667	444 889	25.8263	732	535 824	27.0555	797	635 209	28.2312	862	743 044	29.3598
668	446 224	25.8457	733	537 289	27.0740	798	636 804	28.2489	863	744 769	29.3769
669	447 561	25.8650	734	538 756	27.0924	799	638 401	28.2666	864	746 496	29.3939
670	448 900	25.8844	735	540 225	27.1109	800	640 000	28.2843	865	748 225	29.4109
671	450 241	25.9037	736	541 696	27.1293	801	641 601	28.3019	866	749 956	29.4279
672	451 584	25.9230	737	543 169	27.1477	802	643 204	28.3196	867	751 689	29.4449
673	452 929	25.9422	738	544 644	27.1662	803	644 809	28.3373	868	753 424	29.4618
674	454 276	25.9615	739	546 121	27.1846	804	646 416	28.3549	869	755 161	29.4788
675	455 625	25.9808	740	547 600	27.2029	805	648 025	28.3725	870	756 900	29.4958
676	456 976	26.0000	741	549 081	27.2213	806	649 636	28.3901	871	758 641	29.5127
677	458 329	26.0192	742	550 564	27.2397	807	651 249	28.4077	872	760 384	29.5296
678	459 684	26.0384	743	552 049	27.2580	808	652 864	28.4253	873	762 129	29.5466
679	461 041	26.0576	744	553 536	27.2764	809	654 481	28.4429	874	763 876	29.5635
680	462 400	26.0768	745	555 025	27.2947	810	656 100	28.4605	875	765 625	29.5804
681	463 761	26.0960	746	556 516	27.3130	811	657 721	28.4781	876	767 376	29.5973
682	465 124	26.1151	747	558 009	27.3313	812	659 344	28.4956	877	769 129	29.6142
683	466 489	26.1343	748	559 504	27.3496	813	660 969	28.5132	878	770 884	29.6311
684	467 856	26.1534	749	561 001	27.3679	814	662 596	28.5307	879	772 641	29.6479
685	469 225	26.1725	750	562 500	27.3861	815	664 225	28.5482	880	774 400	29.6648
686	470 596	26.1916	751	564 001	27.4044	816	665 856	28.5657	881	776 161	29.6816
687	471 969	26.2107	752	565 504	27.4226	817	667 489	28.5832	882	777 924	29.6985
688	473 344	26.2298	753	567 009	27.4408	818	669 124	28.6007	883	779 689	29.7153
689	474 721	26.2488	754	568 516	27.4591	819	670 761	28.6182	884	781 456	29.7321
690	476 100	26.2679	755	570 025	27.4773	820	672 400	28.6356	885	783 225	29.7489
691	477 481	26.2869	756	571 536	27.4955	821	674 041	28.6531	886	784 996	29.7658
692	478 864	26.3059	757	573 049	27.5136	822	675 684	28.6705	887	786 769	29.7825
693	480 249	26.3249	758	574 564	27.5318	823	677 329	28.6880	888	788 544	29.7993
694	481 636	26.3439	759	576 081	27.5500	824	678 976	28.7054	889	790 321	29.8161
695	483 025	26.3629	760	577 600	27.5681	825	680 625	28.7228	890	792 100	29.8329
696	484 416	26.3818	761	579 121	27.5862	826	682 276	28.7402	891	793 881	29.8496
697	485 809	26.4008	762	580 644	27.6043	827	683 929	28.7576	892	795 664	29.8664
698	487 204	26.4197	763	582 169	27.6225	828	685 584	28.7750	893	797 449	29.8831
699	488 601	26.4386	764	583 696	27.6405	829	687 241	28.7924	894	799 236	29.8998
700	490 000	26.4575	765	585 225	27.6586	830	688 900	28.8097	895	801 025	29.9166
701	491 401	26.4764	766	586 756	27.6767	831	690 561	28.8271	896	802 816	29.9333
702	492 804	26.4953	767	588 289	27.6948	832	692 224	28.8444	897	804 609	29.9500
703	494 209	26.5141	768	589 824	27.7128	833	693 889	28.8617	898	806 404	29.9666
704	495 616	26.5330	769	591 361	27.7308	834	695 556	28.8791	899	808 201	29.9833
705	497 025	26.5518	770	592 900	27.7489	835	697 225	28.8964	900	810 000	30.0000
706	498 436	26.5707	771	594 441	27.7669	836	698 896	28.9137	901	811 801	30.0167
707	499 849	26.5895	772	595 984	27.7849	837	700 569	28.9310	902	813 604	30.0333
708	501 264	26.6083	773	597 529	27.8029	838	702 244	28.9482	903	815 409	30.0500
709	502 681	26.6271	774	599 076	27.8209	839	703 921	28.9655	904	817 216	30.0666
710	504 100	26.6458	775	600 625	27.8388	840	705 600	28.9828	905	819 025	30.0832
711	505 521	26.6646	776	602 176	27.8568	841	707 281	29.0000	906	820 836	30.0998
712	506 944	26.6833	777	603 729	27.8747	842	708 964	29.0172	907	822 649	30.1164
713	508 369	26.7021	778	605 284	27.8927	843	710 649	29.0345	908	824 464	30.1330
714	509 796	26.7208	779	606 841	27.9106	844	712 336	29.0517	909	826 281	30.1496

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
910	828 100	30.1662	975	950 625	31.2250	1040	1 081 600	32.2490	1105	1 221 025	33.2415
911	829 921	30.1828	976	952 576	31.2410	1041	1 083 681	32.2645	1106	1 223 236	33.2566
912	831 744	30.1993	977	954 529	31.2570	1042	1 085 764	32.2800	1107	1 225 449	33.2716
913	833 569	30.2159	978	956 484	31.2730	1043	1 087 849	32.2955	1108	1 227 664	33.2866
914	835 396	30.2324	979	958 441	31.2890	1044	1 089 936	32.3110	1109	1 229 881	33.3017
915	837 225	30.2490	980	960 400	31.3050	1045	1 092 025	32.3265	1110	1 232 100	33.3167
916	839 056	30.3655	981	962 361	31.3209	1046	1 094 116	32.3419	1111	1 234 321	33.3317
917	840 889	30.2820	982	964 324	31.3369	1047	1 096 209	32.3574	1112	1 236 544	33.3467
918	842 724	30.2985	983	966 289	31.3528	1048	1 098 304	32.3728	1113	1 238 769	33.3617
919	844 561	30.3150	984	968 256	31.3688	1049	1 100 401	32.3883	1114	1 240 996	33.3766
920	846 400	30.3315	985	970 225	31.3847	1050	1 102 500	32.4037	1115	1 243 225	33.3916
921	848 241	30.3480	986	972 196	31.4006	1051	1 104 601	32.4191	1116	1 245 456	33.4066
922	850 084	30.3645	987	974 169	31.4166	1052	1 106 704	32.4345	1117	1 247 689	33.4215
923	851 929	30.3809	988	976 144	31.4325	1053	1 108 809	32.4500	1118	1 249 924	33.4365
924	853 776	30.3974	989	978 121	31.4484	1054	1 110 916	32.4654	1119	1 252 161	33.4515
925	855 625	30.4138	990	980 100	31.4643	1055	1 113 025	32.4808	1120	1 254 400	33.4664
926	857 476	30.4302	991	982 081	31.4802	1056	1 115 136	32.4962	1121	1 256 641	33.4813
927	859 329	30.4467	992	984 064	31.4960	1057	1 117 249	32.5115	1122	1 258 884	33.4963
928	861 184	30.4631	993	986 049	31.5119	1058	1 119 364	32.5269	1123	1 261 129	33.5112
929	863 041	30.4795	994	988 036	31.5278	1059	1 121 481	32.5423	1124	1 263 376	33.5261
930	864 900	30.4959	995	990 025	31.5436	1060	1 123 600	32.5576	1125	1 265 625	33.5410
931	866 761	30.5123	996	992 016	31.5595	1061	1 125 721	32.5730	1126	1 267 876	33.5559
932	868 624	30.5287	997	994 009	31.5753	1062	1 127 844	32.5883	1127	1 270 129	33.5708
933	870 489	30.5450	998	996 004	31.5911	1063	1 129 969	32.6036	1128	1 272 384	33.5857
934	872 356	30.5614	999	998 001	31.6070	1064	1 132 096	32.6190	1129	1 274 641	33.6006
935	874 225	30.5778	1000	1 000 000	31.6228	1065	1 134 225	32.6343	1130	1 276 900	33.6155
936	876 096	30.5941	1001	1 002 001	31.6386	1066	1 136 356	32.6497	1131	1 279 161	33.6303
937	877 969	30.6105	1002	1 004 004	31.6544	1067	1 138 489	32.6650	1132	1 281 424	33.6452
938	879 844	30.6268	1003	1 006 009	31.6702	1068	1 140 624	32.6803	1133	1 283 689	33.6601
939	881 721	30.6431	1004	1 008 016	31.6860	1069	1 142 761	32.6956	1134	1 285 956	33.6749
940	883 600	30.6594	1005	1 010 025	31.7017	1070	1 144 900	32.7109	1135	1 288 225	33.6898
941	885 481	30.6757	1006	1 012 036	31.7175	1071	1 147 041	32.7261	1136	1 290 496	33.7046
942	887 364	30.6920	1007	1 014 049	31.7333	1072	1 149 184	32.7414	1137	1 292 769	33.7174
943	889 249	30.7083	1008	1 016 064	31.7490	1073	1 151 329	32.7567	1138	1 295 044	33.7342
944	891 136	30.7246	1009	1 018 081	31.7648	1074	1 153 476	32.7719	1139	1 297 321	33.7491
945	893 025	30.7409	1010	1 020 100	31.7805	1075	1 155 625	32.7872	1140	1 299 600	33.7639
946	894 916	30.7571	1011	1 022 121	31.7962	1076	1 157 776	32.8024	1141	1 301 881	33.7787
947	896 809	30.7734	1012	1 024 144	31.8119	1077	1 159 929	32.8177	1142	1 304 164	33.7935
948	898 704	30.7896	1013	1 026 169	31.8277	1078	1 162 084	32.8329	1143	1 306 449	33.8083
949	900 601	30.8058	1014	1 028 196	31.8434	1079	1 164 241	32.8481	1144	1 308 736	33.8231
950	902 500	30 8221	1015	1 030 225	31.8591	1080	1 166 400	32.8634	1145	1 311 025	33.8378
951	904 401	30.8383	1016	1 032 256	31.8748	1081	1 168 561	32.8786	1146	1 313 316	33.8526
952	906 304	30.8545	1017	1 034 289	31.8904	1082	1 170 724	32.8938	1147	1 315 609	33.8674
953	908 209	30.8707	1018	1 036 324	31.9061	1083	1 172 889	32.9090	1148	1 317 904	33.8821
954	910 116	30.8869	1019	1 038 361	31.9218	1084	1 175 056	32.9242	1149	1 320 201	33.8969
955	912 025	30.9031	1020	1 040 400	31.9374	1085	1 177 225	32.9393	1150	1 322 500	33.9116
956	913 936	30.9192	1021	1 042 441	31.9531	1086	1 179 396	32.9545	1151	1 324 801	33.9264
957	915 849	30.9354	1022	1 044 484	31.9687	1087	1 181 569	32.9697	1152	1 327 104	33.9411
958	917 764	30.9516	1023	1 046 529	31.9844	1088	1 183 744	32.9848	1153	1 329 409	33.9559
959	919 681	30.9677	1024	1 048 576	32.0000	1089	1 185 921	33.0000	1154	1 331 716	33.9706
960	921 600	30.9839	1025	1 050 625	32.0156	1090	1 188 100	33.0151	1155	1 334 025	33.9853
961	923 521	31.0000	1026	1 052 676	32.0312	1091	1 190 281	33.0303	1156	1 336 336	34.0000
962	925 444	31.0161	1027	1 054 729	32.0468	1092	1 192 464	33.0454	1157	1 338 649	34.0147
963	927 369	31.0322	1028	1 056 784	32.0624	1093	1 194 649	33.0606	1158	1 340 964	34.0294
964	929 296	31.0483	1029	1 058 841	32.0780	1094	1 196 836	33.0757	1159	1 343 281	34.0441
965	931 225	31.0644	1030	1 060 900	32.0936	1095	1 199 025	33.0908	1160	1 345 600	34.0588
966	933 156	31.0805	1031	1 062 961	32.1092	1096	1 201 216	33.1059	1161	1 347 921	34.0735
967	935 089	31.0966	1032	1 065 024	32.1248	1097	1 203 409	33.1210	1162	1 350 244	34.0881
968	937 024	31.1127	1033	1 067 089	32.1403	1098	1 205 604	33.1361	1163	1 352 569	34.1028
969	938 961	31.1288	1034	1 069 156	32.1559	1099	1 207 801	33.1512	1164	1 354 896	34.1174
970	940 900	31.1448	1035	1 071 225	32.1714	1100	1 210 000	33.1662	1165	1 357 225	34.1321
971	942 841	31.1609	1036	1 073 296	32.1870	1101	1 212 201	33.1813	1166	1 359 556	34.1467
972	944 784	31.1769	1037	1 075 369	32.2025	1102	1 214 404	33.1964	1167	1 361 889	34.1614
973	946 729	31.1929	1038	1 077 444	32.2180	1103	1 216 609	33.2114	1168	1 354 224	34.1760
974	948 676	31.2090	1039	1 079 521	32.2335	1104	1 218 816	33.2264	1169	1 366 561	34.1906

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
1170	1 368 900	34.2053	1235	1 525 225	35.1426	1300	1 690 000	36.0555	1365	1 863 225	36.9459
1171	1 371 241	34.2199	1236	1 527 696	35.1568	1301	1 692 601	36.0694	1366	1 865 956	36.9594
1172	1 373 584	34.2345	1237	1 530 169	35.1710	1302	1 695 204	36.0832	1367	1 868 689	36.9730
1173	1 375 929	34.2491	1238	1 532 644	35.1852	1303	1 697 809	36.0971	1368	1 871 424	36.9865
1174	1 378 276	34.2637	1239	1 535 121	35.1994	1304	1 700 416	36.1109	1369	1 874 161	37.0000
1175	1 380 625	34.2783	1240	1 537 600	35.2136	1305	1 703 025	36.1248	1370	1 876 900	37.0135
1176	1 382 976	34.2929	1241	1 540 081	35.2278	1306	1 705 636	36.1386	1371	1 879 641	37.0270
1177	1 385 329	34.3074	1242	1 542 564	35.2420	1307	1 708 249	36 1525	1372	1 882 384	37.0405
1178	1 387 684	34.3220	1243	1 545 049	35.2562	1308	1 710 864	36.1663	1373	1 885 129	37.0540
1179	1 390 041	34.3366	1244	1 547 536	35.2704	1309	1 713 481	36.1801	1374	1 887 876	37.0675
1180	1 392 400	34.3511	1245	1 550 025	35.2846	1310	1 716 100	36.1939	1375	1 890 625	37.0810
1181	1 394 761	34.3657	1246	1 552 516	35.2987	1311	1 718 721	36.2077	1376	1 893 376	37.0945
1182	1 397 124	34.3802	1247	1 555 009	35.3129	1312	1 721 344	36.2215	1377	1 896 129	37.1080
1183	1 399 489	34.3948	1248	1 557 504	35.3270	1313	1 723 969	36.2353	1378	1 898 884	37.1214
1184	1 401 856	34.4093	1249	1 560 001	35.3412	1314	1 726 596	36.2491	1379	1 901 641	37.1349
1185	1 404 225	34.4238	1250	1 562 500	35.3553	1315	1 729 225	36.2629	1380	1 904 400	37.1484
1186	1 406 596	34.4384	1251	1 565 001	35.3695	1316	1 731 856	36.2767	1381	1 907 161	37.1618
1187	1 408 969	34.4529	1252	1 567 504	35.3836	1317	1 734 489	36.2905	1382	1 909 924	37.1753
1188	1 411 344	34.4674	1253	1 570 009	35.3977	1318	1 737 124	36.3043	1383	1 912 689	37.1887
1189	1 413 721	34.4819	1254	1 572 516	35.4119	1319	1 739 761	36.3180	1384	1 915 456	37.2021
1190	1 416 100	34.4964	1255	1 575 025	35.4260	1320	1 742 400	36.3318	1385	1 918 225	37 2156
1191	1 418 481	34.5109	1256	1 577 536	35.4401	1321	1 745 041	36.3456	1386	1 920 996	37.2290
1192	1 420 864	34.5254	1257	1 580 049	35.4542	1322	1 747 684	36.3593	1387	1 923 769	37.2424
1193	1 423 249	34.5398	1258	1 582 564	35.4683	1323	1 750 329	36.3731	1388	1 926 544	37.2559
1194	1 425 636	34.5543	1259	1 585 081	35.4824	1324	1 752 976	36.3868	1389	1 929 321	37.2693
1195	1 428 025	34.5688	1260	1 587 600	35.4965	1325	1 755 625	36.4005	1390	1 932 100	37 2827
1196	1 430 416	34.5832	1261	1 590 121	35 5106	1326	1 758 276	36.4143	1391	1 934 881	37.2961
1197	1 432 809	34.5977	1262	1 592 644	35.5246	1327	1 760 929	36.4280	1392	1 937 664	37.3095
1198	1 435 204	34.6121	1263	1 595 169	35.5387	1328	1 763 584	36.4417	1393	1 940 449	37.3229
1199	1 437 601	34.6266	1264	1 597 696	35.5528	1329	1 766 241	36.4555	1394	1 943 236	37.3363
1200	1 440 000	34.6410	1265	1 600 225	35.5668	1330	1 768 900	36.4692	1395	1 946 025	37.3497
1201	1 442 401	34.6554	1266	1 602 756	35.5809	1331	1 771 561	36.4829	1396	1 948 816	37.3631
1202	1 444 804	34.6699	1267	1 605 289	35.5949	1332	1 774 224	36.4966	1397	1 951 609	37.3765
1203	1 447 209	34.6843	1268	1 607 824	35.6090	1333	1 776 889	36.5103	1398	1 954 404	37.3898
1204	1 449 616	34.6987	1269	1 610 361	35.6230	1334	1 779 556	36.5240	1399	1 957 201	37.4032
1205	1 452 025	34.7131	1270	1 612 900	35.6371	1335	1 782 225	36.5377	1400	1 960 000	37.4166
1206	1 454 436	34.7275	1271	1 615 441	35.6511	1336	1 784 896	36.5513	1401	1 962 801	37 4299
1207	1 456 849	34.7419	1272	1 617 984	35.6651	1337	1 787 569	36.5650	1402	1 965 604	37 4433
1208	1 459 264	34.7563	1273	1 620 529	35.6791	1338	1 790 244	36.5787	1403	1 968 409	37.4566
1209	1 461 681	34.7707	1274	1 623 076	35.6931	1339	1 792 921	36.5923	1404	1 971 216	37.4700
1210	1 464 100	34.7851	1275	1 625 625	35.7071	1340	1 795 600	36.6060	1405	1 974 025	37.4833
1211	1 466 521	34.7994	1276	1 628 176	35.7211	1341	1 798 281	36.6197	1406	1 976 836	37.4967
1212	1 468 944	34.8138	1277	1 630 729	35.7351	1342	1 800 964	36.6333	1407	1 979 649	37.5100
1213	1 471 369	34.8281	1278	1 633 284	35.7491	1343	1 803 649	36.6469	1408	1 982 464	37.5233
1214	1 473 796	34.8425	1279	1 635 841	35.7631	1344	1 806 336	36.6606	1409	1 985 281	37.5366
1215	1 476 225	34.8569	1280	1 638 400	35.7771	1354	1 809 025	36.6742	1410	1 988 100	37.5500
1216	1 478 656	34.8712	1281	1 640 961	35.7911	1346	1 811 716	36.6879	1411	1 990 921	37.5633
1217	1 481 089	34.8855	1282	1 643 524	35.8050	1347	1 814 409	36.7015	1412	1 993 744	37.5766
1218	1 483 524	34.8999	1283	1 646 089	35.8190	1348	1 817 104	36.7151	1413	1 996 569	37.5899
1219	1 485 961	34.9142	1284	1 648 656	35.8329	1349	1 819 801	36.7287	1414	1 999 396	37.6032
1220	1 488 400	34.9285	1285	1 651 225	35.8469	1350	1 822 500	36.7423	1415	2 002 225	37.6165
1221	1 490 841	34.9428	1286	1 653 796	35.8608	1351	1 825 201	36.7560	1416	2 005 056	37.6298
1222	1 493 284	34.9571	1287	1 656 369	35.8748	1352	1 827 904	36.7696	1417	2 007 889	37.6431
1223	1 495 729	34.9714	1288	1 658 944	35.8887	1353	1 830 609	36.7831	1418	2 010 724	37.6563
1224	1 498 176	34.9857	1289	1 661 521	35.9026	1354	1 833 316	36.7967	1419	2 013 561	37.6696
1225	1 500 625	35.0000	1290	1 664 100	35.9166	1355	1 836 025	36.8103	1420	2 016 400	37.6829
1226	1 503 076	35.0143	1291	1 666 681	35.9305	1356	1 838 736	36.8239	1421	2 019 241	37.6962
1227	1 505 529	35.0286	1292	1 669 264	35.9444	1357	1 841 449	36.8375	1422	2 022 084	37.7094
1228	1 507 984	35.0428	1293	1 671 849	35.9583	1385	1 844 164	36.8511	1423	2 024 929	37.7227
1229	1 510 441	35.0571	1294	1 674 436	35.9722	1359	1 846 881	36.8646	1424	2 027 776	37.7359
1230	1 512 900	35.0714	1295	1 677 025	35.9861	1360	1 849 600	36.8782	1425	2 030 625	37.7492
1231	1 515 361	35.0856	1296	1 679 616	36.0000	1361	1 852 321	36.8917	1426	2 033 476	37.7624
1232	1 517 824	35.0999	1297	1 682 209	36.0139	1362	1 855 044	36.9053	1427	2 036 329	37.7757
1233	1 520 289	35.1141	1298	1 684 804	36.0278	1363	1 857 769	36.9188	1428	2 039 184	37.7889
1234	1 522 756	35.1283	1299	1 687 401	36.0416	1364	1 860 496	36.9324	1429	2 042 041	37.8021

SQUARES AND SQUARE ROOTS (*Continued*)

No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root	No.	Square	Square Root
1430	**2 044 900**	**37.8153**	1475	2 175 625	38.4057	1520	2 310 400	38.9872	1560	2 433 600	39.4968
1431	**2 047 761**	**37.8286**	1476	2 178 576	38.4187	1521	2 313 441	39.0000	1561	2 436 721	39.5095
1432	**2 050 624**	**37.8418**	1477	2 181 529	38.4318	1522	2 316 484	39.0128	1562	2 439 844	39.5221
1433	**2 053 489**	**37.8550**	1478	2 184 484	38.4448	1523	2 319 529	39.0256	1563	2 442 969	39.5348
1434	**2 056 356**	**37.8682**	1479	2 187 441	38.4578	1524	2 322 576	39.0384	1564	2 446 096	39.5474
1435	**2 059 225**	**37.8814**	1480	2 190 400	38 4708	1525	2 325 625	39.0512	1565	2 449 225	39.5601
1436	**2 062 096**	**37.8946**	1481	2 193 361	38.4838	1526	2 328 676	39.0640	1566	2 452 356	39.5727
1437	**2 064 969**	**37.9078**	1482	2 196 324	38.4968	1527	2 331 729	39.0768	1567	2 455 489	39.5854
1438	**2 067 844**	**37.9210**	1483	2 199 289	38.5097	1528	2 334 784	39.0896	1568	2 458 624	39.5980
1439	**2 070 721**	**37.9342**	1484	2 202 256	38.5227	1529	2 337 841	39.1024	1569	2 461 761	39.6106
1440	**2 073 600**	**37.9473**	1485	2 205 225	38.5357	1530	2 340 900	39.1152	1570	2 464 900	39 6232
1441	**2 076 481**	**37.9605**	1486	2 208 196	38.5487	1531	2 343 961	39.1280	1571	2 468 041	39.6358
1442	**2 079 364**	**37.9737**	1487	2 211 169	38.5616	1532	2 347 024	39.1408	1572	2 471 184	39.6485
1443	**2 082 249**	**37.9868**	1488	2 214 144	38.5746	1533	2 350 089	39.1535	1573	2 474 329	39.6611
1444	**2 085 136**	**38.0000**	1489	2 217 121	38.5876	1534	2 353 156	39.1663	1574	2 477 476	39.6737
1445	**2 088 025**	**38 0132**	1490	2 220 100	38.6005	1535	2 356 225	39.1791	1575	2 480 625	39.6863
1446	**2 090 916**	**38.0263**	1491	2 223 081	38.6135	1536	2 359 296	39.1918	1576	2 483 776	39.6989
1447	**2 093 809**	**38.0395**	1492	2 226 064	38.6264	1537	2 362 369	39.2046	1577	2 486 929	39.7115
1448	**2 096 704**	**38.0526**	1493	2 229 049	38.6394	1538	2 365 444	39.2173	1578	2 490 084	39.7240
1449	**2 099 601**	**38.0657**	1494	2 232 036	38.6523	1539	2 368 521	39.2301	1579	2 493 241	39.7366
1450	**2 102 500**	**38.0789**	1495	2 235 025	38.6652	1540	2 371 600	39.2428	1580	2 496 400	39.7492
1451	**2 105 401**	**38.0920**	1496	2 238 016	38.6782	1541	2 374 681	39.2556	1581	2 499 561	39.7618
1452	**2 108 304**	**38.1051**	1497	2 241 009	38.6911	1542	2 377 764	39.2683	1582	2 502 724	39.7744
1453	**2 111 209**	**38.1182**	1498	2 244 004	38.7040	1543	2 380 849	39.2810	1583	2 505 889	39.7869
1454	**2 114 116**	**38.1314**	1499	2 247 001	38.7169	1544	2 383 936	39.2938	1584	2 509 056	39.7995
1455	**2 117 025**	**38.1445**	1500	2 250 000	38.7298	1545	2 387 025	39.3065	1585	2 512 225	39.8121
1456	**2 119 936**	**38.1576**	1501	2 253 001	38.7427	1546	2 390 116	39.3192	1586	2 515 396	39.8246
1457	**2 122 849**	**38.1707**	1502	2 256 004	38.7556	1547	2 393 209	39.3319	1587	2 518 569	39.8372
1458	**2 125 764**	**38.1838**	1503	2 259 009	38.7685	1548	2 396 304	39.3446	1588	2 521 744	39.8497
1459	**2 128 681**	**38.1969**	1504	2 262 016	38.7814	1549	2 399 401	39.3573	1589	2 524 921	39.8623
1460	**2 131 600**	**38.2099**	1505	2 265 025	38.7943	1550	2 402 500	39.3700	1590	2 528 100	39.8748
1461	**2 134 521**	**38.2230**	1506	2 268 036	38.8072	1551	2 405 601	39.3827	1591	2 531 281	39.8873
1462	**2 137 444**	**38.2361**	1507	2 271 049	38.8201	1552	2 408 704	39.3954	1592	2 534 464	39.8999
1463	**2 140 369**	**38.2492**	1508	2 274 064	38.8330	1553	2 411 809	39.4081	1593	2 537 649	39.9124
1464	**2 143 296**	**38.2623**	1509	2 277 081	38.8458	1554	2 414 916	39.4208	1594	2 540 836	39.9249
1465	**2 146 225**	**38.2753**	1510	2 280 100	38.8587	1555	2 418 025	39.4335	1595	2 544 025	39.9375
1466	**2 149 156**	**38.2884**	1511	2 283 121	38.8716	1556	2 421 136	39.4462	1596	2 547 216	39.9500
1467	**2 152 089**	**38.3014**	1512	2 286 144	38.8844	1557	2 424 249	39.4588	1597	2 550 409	39.9625
1468	**2 155 024**	**38.3145**	1513	2 289 169	38.8973	1558	2 427 364	39.4715	1598	2 553 604	39.9750
1469	**2 157 961**	**38.3275**	1514	2 292 196	38.9102	1559	2 430 481	39.4842	1599	2 556 801	39.9875
1470	**2 160 900**	**38.3406**	1515	2 295 225	38.9230				1600	2 560 000	40.0000
1471	**2 163 841**	**38.3536**	1516	2 298 256	38.9358						
1472	**2 166 784**	**38.3667**	1517	2 301 289	38.9487						
1473	**2 169 729**	**38.3797**	1518	2 304 324	38.9615						
1474	**2 172 676**	**38.3927**	1519	2 307 361	38.9744						

REPORT OF COMMITTEE C-9

ON

CONCRETE AND CONCRETE AGGREGATES

It is with a sense of pardonable pride that Committee C-9 presents a report of the work of the main committee, of the accomplishments of its subcommittees and some of its active members during the past year. The gradual, progressive and continuous reorganization of the committee, under a plan of short term appointments to membership on the committee and on subcommittees, with reappointments for meritorious service, is in progress, and the results to date, as evidenced by the volume of work accomplished during the past year, indicate the wisdom of the policy.

The committee held two well-attended all-day meetings during the winter, one in Washington in December, and one in Detroit, Mich., in March, in conjunction with the group committee meetings. In addition, numerous subcommittee meetings have been held. The present membership of the committee is 59 classified as 25 producers, 19 consumers and 15 general interests.

Some of the more important activities of the committee are presented herewith and in separate papers, appended hereto, by members of the committee.

The chief function of this portion of the report will be to present certain recommendations relating to standards and tentative standards under the jurisdiction of Committee C-9, to outline very briefly the activities of the subcommittees, and to call attention to the separate papers appended hereto.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Proposed New Tentative Standard:

The committee recommends for publication as tentative the Proposed Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading, which has been prepared by Subcommittee VII on Strength Tests of Concrete. This proposed method is appended hereto.[1]

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[1] See p. 1027.—ED.

The reasons for, and the basis of, the proposed method are as follows: In highway work it is rapidly becoming recognized that the flexure test is a valuable means for determining the quality of the concrete. At the present time a large number of states are making flexure specimens in the field and there is a wide variety of methods being used for making the specimens and also for testing them. The need for the standardization of a proper flexure test is very pressing. A considerable amount of laboratory work has been done on the flexure testing of concrete and the data for the formulation of the present standard was obtained very largely from the work of the Portland Cement Association, as published in the Report of the Director of Research for 1928. The Portland Cement Association investigations cover the question of size of beam in relation to the size of the aggregate, the point of load application and a number of other matters important in the formulation of a standard. Committee C-9 has taken into consideration as fully as possible the existing data on beam testing in drawing up the standard at present proposed.

Advancement of Tentative Standards to Standard:

The committee recommends that the following three tentative methods be revised as indicated and advanced to standard:

Tentative Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 – 28 T):[1]

Title.—Change the title from its present form as given above by the omission of the words "field determination of".

Section 5.—Change to read as follows by the addition of the italicized word and the omission of the word in brackets:

> 5. The approximate apparent specific gravity of the fine aggregate [may] *shall* be calculated from the formula:

Section 6.—The second sentence of this section is explanatory in nature and it is recommended that it appear as a note in the method.

Tentative Method of Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 – 28 T):[2]

Title.—Change the title from its present form to read as follows by the addition of the italicized word and the omission of the word in brackets:

> Tentative Method of Test for [Field Determination of] Approximate Percentage of Voids in *Inundated* Fine Aggregate.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 827 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 212.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 829 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 214.

Section 4.—Change the fifth sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

The aggregate in the flask shall [not] be agitated during [or after] the filling operation *to insure the elimination of entrained air.*

Section 5.—Change Paragraph (*a*) from its present form: namely,

5. (*a*) This method requires that the apparent specific gravity be known of the fine aggregate in a room-dry, free flowing condition, but with the voids within the particles of the aggregate containing moisture. If the apparent specific gravity of the aggregate in this condition is not known it shall be determined in accordance with the Tentative Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (A.S.T.M. Designation: C 68 - 28 T) of the American Society for Testing Materials.

to read as follows:

5. (*a*) This method requires that the apparent specific gravity of the fine aggregate, determined in accordance with the Tentative Method of Test for Determination of Approximate Apparent Specific Gravity of Fine Aggregate (A.S.T.M. Designation: C 68 - 28 T) of the American Society for Testing Materials, be known.

Change the first sentence of Paragraph (*b*) to read as follows, by the addition of the italicized word and the omission of the word in brackets:

(*b*) The approximate percentage of voids in the inundated fine aggregate [may] *shall* be calculated from the formula:

Section 6.—The second sentence of this section is explanatory in nature and it is recommended that it appear as a note in the method.

Tentative Method of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 - 28 T):[1]

Title.—Change the title from its present form as given above by the omission of the words "field determination of".

Section 1.—Change the first sentence to read as follows by the omission of the words in brackets:

1. This method of test is intended for use in [the field for] making approximate determinations of the percentage of surface moisture in fine aggregate [for use in computing the allowance to be made for water in the fine aggregate when proportioning concrete by the maximum water content method].

Section 3.—Change from its present form: namely,

3. A sample weighing about 1 kg. shall be selected which shall be as truly representative of the fine aggregate as possible. It shall be well mixed and spread out on a flat non-absorbent surface. Five hundred grams shall be imme-

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 832 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 217.

diately weighed out, permitting moisture to evaporate as little as possible from the sample.

to read as follows:

3. A sample weighing 1 kg. shall be selected which shall be as truly representative of the fine aggregate as possible. It shall be well mixed and 500 g. shall be immediately weighed out permitting moisture to evaporate as little as possible from the sample.

Section 5.—Change Paragraph (*a*) from its present form: namely,

5. (*a*) This method requires that the apparent specific gravity be known of the fine aggregate in a room-dry, free-flowing condition, but with the voids within the particles of the aggregate containing moisture. If the apparent specific gravity of the aggregate in this condition is not known it shall be determined in accordance with the Tentative Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (A.S.T.M. Designation: C 68 – 28 T) of the American Society for Testing Materials.

to read as follows:

5. (*a*) This method requires that the apparent specific gravity of the fine aggregate, determined in accordance with the Tentative Method of Test for Determination of Approximate Apparent Specific Gravity of Fine Aggregate (A.S.T.M. Designation: C 68 – 28 T) of the American Society for Testing Materials, be known.

Change the first sentence of Paragraph (*b*) to read as follows by the addition of the italicized word and the omission of the word in brackets:

(*b*) The percentage of surface moisture in the fine aggregate (air dry basis) [may] *shall* be calculated from the formula:

Section 6.—The second sentence of this section is explanatory in nature and it is recommended that it appear as a note in the method.

Tentative Revision of a Standard:

The committee recommends that the tentative revision proposed last year[1] in the Standard Methods of Making and Storing Specimens of Concrete in the Field (C 31 – 27) be continued as tentative with the following change in the proposed new Section 7.

New Section 7.—Change the last sentence in Paragraph (*b*) from the form in which it was proposed last year: namely,

They shall be sent to the laboratory not more than 7 days prior to the time of test and while in the laboratory shall be kept in ordinary air at room temperatures until tested.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 864; also 1929 Book of A.S.T.M. Tentative Standards, p. 818.

to read as follows:

> For 28-day tests the specimens shall be sent to the laboratory not more than 7 days prior to the time of test. For other periods of test the specimens shall be kept in the field at least three-fourths of the test period. In any case, while in the laboratory the specimens shall be kept in ordinary air at room temperatures until tested.

It is rather obvious that the reason for proposing this change is to make more specific the instructions regarding time of transferring test specimens from the field storage to the laboratory.

The committee also recommends that the title of the Standard Methods of Making and Storing Specimens of Concrete in the Field (C 31 - 27) be revised by the insertion of the words "compression test" before "specimens", making the title read "Standard Methods of Making and Storing Compression Test Specimens of Concrete in the Field." The purpose of this latter change is to clearly distinguish this procedure of making compression test specimens from the method given in the newly proposed flexure test and since it is editorial it is recommended that it be made immediately.

The committee recommends that the Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 - 27) with certain editorial revisions proposed by Subcommittee IV be submitted to the American Standards Association for adoption as American Standard under the Proprietary Standard Method of A.S.A. procedure.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED TENTATIVE STANDARD			
Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading	41	2	2
II. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Method of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 - 28 T)	39	1	5
Method of Test for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 - 28 T)	39	1	5
Method of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 - 28 T)	37	2	6
III. PROPOSED REVISION OF STANDARD			
Method of Making and Storing Specimens of Concrete in the Field (C 31 - 27)	42	1	2

ACTIVITIES OF SUBCOMMITTEES

Subcommittee III on Unification of Specifications (W. A. Slater, chairman).—This subcommittee is assembling into a general specification for concrete, requirements for the various ingredients and methods of test involved. Naturally this committee is dependent upon the other subcommittees of Committee C-9 for material for its report, and the greatest difficulty with which it has to contend is the fact that the various subcommittees hesitate to write specifications while investigational work on the subject under consideration is still unfinished. However, as research work of this kind is never finished, it is necessary that, in some cases at least, the best specifications that can be written with the information now available be prepared.

The tentative draft of the subcommittee's specifications for concrete uses the Standard Specification and Tests for Portland Cement (C 9 – 26), the Tentative Specification for Concrete Aggregates (C 33 – 28 T) and the various methods of test specified in these specifications. It is depending upon the other subcommittees for (1) a standard method for design of mixes, (2) specifications for mixing, (3) specifications for curing, and (4) specifications for admixtures. This subcommittee has also prepared certain specifications which do not appear to fall within the scope of any of the other subcommittees of Committee C-9.

This subcommittee takes the position that it should deal only with the manufacturing processes of concrete and not with the fabrication of the concrete into a structure, that is, with form work, reinforcement and depositing of concrete. except insofar as these matters may affect the quality of the concrete. In this view Committee C-9 has concurred.

Suncommittee IV, Editorial (F. B. Lysle, chairman).—As a result of a very comprehensive review by this subcommittee of the standards under the jurisdiction of Committee C-9, a number of revisions of an editorial nature are being made and several changes in the substance of the standards have been referred to the subcommittees concerned for consideration.

Subcommittee V, Definitions (Ernest Ashton, chairman.)—This subcommittee has recently been reorganized under the present chairman. It has a large number of definitions under consideration, but does not recommend any action at this time.

Subcommittee VII on Strength Tests of Concrete (A. T. Goldbeck, chairman).—A method of capping concrete test specimens using a sand cushion is described in report of D. D. McGuire, which appears as Appendix I to this report. This method possesses the merits of simplicity and speed. It is hoped that the publication of this description of the method will stimulate a desire to try it in many laboratories, and that careful investigations will be made of its merits and faults.

Another method of capping concrete specimens, involving the use of molten sulfur, and which is particularly adapted to use on specimens having uneven end surfaces, is described in a brief paper by P. J. Freeman. This description appears as Appendix II to this report.

The growing tendency to use coarse aggregate ranging in size from 2 to 6 in. in diameter, and sometimes even larger, has made it desirable to consider a method of test which would reveal the true strength of such concrete without the necessity of using specimens larger than the present usual standard 6 by 12-in. cylinder. A report by F. R. McMillan sets forth a method for testing such concrete and appears as Appendix III.

An investigation of Haydite aggregate has been conducted under the direction of F. E. Richart, a member of this committee, which is of considerable interest in this field. The results of this series of tests are reported to the Society at this meeting in a paper by F. E. Richart and V. P. Jensen, entitled "Tests of Plain and Reinforced Haydite Concrete."[1]

This subcommittee has prepared the proposed Tentative Laboratory Method of Making Flexure Test of Concrete Using the Simple Beam with Center Loading mentioned earlier in this report, and appended hereto,[2] which is being recommended for publication as a tentative standard.

To those interested in the flexure testing of concrete, it may be well to call attention to the selected bibliography which accompanied the paper on "Compression, Flexure and Tension Tests of Plain Concrete" presented before the Society in 1928.[3]

Subcommittee IX on Specifications and Methods of Tests of Aggregates (H. F. Clemmer, chairman).—A study of "Abrasion of Aggregates" has been made by F. H. Jackson, whose report forms Appendix IV.

In the 1929 report of this committee there appeared a report by A. T. Goldbeck on the Effect of Stone Dust on the Properties of Concrete.[4] The results of one year tests on specimens made in this investigation are now available and are included in a report by the same author which forms Appendix V to this report.

An extensive investigation of the relation of loss by abrasion and the unit weight of aggregate to the concrete making qualities of slag has been made by Fred Hubbard, with the cooperation of a number of other laboratories, and the results of tests up to 90 days are reported in Appendix VI.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 674 (1930).

[2] See p. 1027.—ED.

[3] H. F. Gonnerman and E. C. Shuman, "Compression, Flexure and Tension Tests of Plain Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 527 (1928).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 301 (1929).

A comparative study of a number of methods of determining moisture in concrete aggregates has been made by S. H. Graf, assisted by R. H. Johnson, which has resulted in a report entitled "Study of Methods for Determining Moisture in Sand," which appears as Appendix VII[1] to this report.

Attention is called to a paper by W. J. Emmons, Director, Michigan State Highway Laboratory, entitled "Effect of Soft Particles of Coarse Aggregate Upon the Strength and Durability of Concrete," which was presented at the Sixteenth Annual Conference on Highway Engineering,[1] in which the results of an investigation and a series of tests are reported.

The subcommittee recommends the advancement to standard of the Tentative Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate (C 68 – 28 T), for Field Determination of Approximate Percentage of Voids in Fine Aggregate (C 69 – 28 T) and for Field Determination of Surface Moisture in Fine Aggregate (C 70 – 28 T), with revisions, as mentioned earlier in this report. These methods of test have been in use and under investigation for a period of two years and found satisfactory. This recommendation is, therefore, concurred in by Committee C-9, which in turn recommends this action to the Society.

Subcommittee XI on Apparatus for Testing (D. A. Abrams, chairman).—A report on "Apparatus for Flexure Tests of Concrete Beams," which points out and discusses the salient features, both desirable and undesirable, of many types of apparatus designed or proposed for this purpose, prepared by A. T. Goldbeck, is submitted herewith as Appendix VIII.

Subcommittee XII on Measurement of Materials, Mixing and Placing Concrete (R. L. Bertin, chairman).—This subcommittee has paid special attention during the past year to the development of a satisfactory method for quantitative determination of the constituents of fresh concrete. Several methods have been suggested, both by members of the committee and others, and they have been tried out under laboratory and field conditions. It is expected that a report on or papers dealing with this subject will be prepared during the coming year.

This subcommittee offers a bibliography on Mixing Concrete, which was prepared by the Portland Cement Association, and which accompanies this report as Appendix IX.[1] In this bibliography have been incorporated abstracts by A. A. Levison of 38 articles which deal with mixing machinery, and abstracts of 9 articles dealing with general data on concrete, with particular reference to mixing, made by R. W. Crum.

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[1] *Proceedings*, Sixteenth Annual Conference on Highway Engineering held at University of Michigan, Ann Arbor, Mich.

Subcommittee XVI on Elasticity and Volume Changes of Concrete (F. E. Richart, chairman).—This subcommittee is directing its attention chiefly to the collection of data available in the literature and has made a study of some of the published information.

A paper on "Band Type Circumferential Extensometer for Poisson's Ratio Determinations," by C. H. Scholer is presented as Appendix X.

A digest of literature published in the United States on tests for the determination of modulus of elasticity of portland cement mortar and concrete, prepared by L. W. Teller, is appended hereto as Appendix XI.

A Digest of Test Data on Poisson's Ratio for Concrete, by F. E. Richart and N. H. Roy, is presented as Appendix XII.

A Summary of Investigations of Volume Changes in Cements, Mortars, and Concretes Produced by Causes Other than Stress, prepared by R. E. Davis, appears as Appendix XIII.

In addition to the reports listed above, there are being presented at this annual meeting, by members of this subcommittee, the following two papers having an intimate relation to the work of the subcommittee, but which do not form a part of this report, "Volume Change of Concrete," by C. H. Scholer and E. R. Dawley;[1] and "Flow of Concrete Under Sustained Compressive Stress," by R. E. Davis and H. E. Davis.[2]

Subcommittee XVII on Conditions Affecting Durability of Concrete (Ephrem Viens, chairman).—Members of this subcommittee made a nine-day inspection trip examining concrete structures in Ontario and Quebec. An illustrated report of the trip, together with observations and conclusions of the members making it, is appended hereto.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been referred to letter ballot of the committee, which consists of 59 members; 46 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

STANTON WALKER,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 751 (1930).

[2] *Ibid.*, p. 707.

EDITORIAL NOTE

The proposed Tentative Laboratory Method of Making Flexure Tests of Concrete Using a Simple Beam with Center Loading was accepted for publication as tentative and appears on page 1027.

The Tentative Methods of Test for Field Determination of Approximate Apparent Specific Gravity of Fine Aggregate; for Field Determination of Approximate Percentage of Voids in Fine Aggregate; and for Field Determination of Surface Moisture in Fine Aggregate, as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 157, 159 and 162, respectively.

The proposed tentative revision of the Standard Method of Making and Storing Specimens of Concrete in the Field was accepted for publication as tentative and appears on page 1276.

Subsequent to the annual meeting, the committee approved a revision of the Tentative Specifications for Concrete Aggregates. This revision was accepted on September 18 by Committee E-10 on Standards. The specifications in their revised form appear on page 1022.

APPENDIX I

TESTING CONCRETE CYLINDERS USING CONFINED SAND CUSHION

BY D. D. McGUIRE[1]

At the meeting of Committee C-9 held in Chicago, Ill., March, 1929, the question of sand-capping for concrete compression test specimens was discussed and it was pointed out that previous data indicated that sand capping was satisfactory for specimens made of concrete which would develop a compressive strength not in excess of 2500 lb. per sq. in. This statement was questioned, and it was brought out that the Tennessee Highway Department regularly used sand capping of a restrained nature on concrete specimens developing a strength of 3500 lb. per sq. in. or more. The problem of furnishing additional data was assigned to the author, and it was requested that the use of confined sand for capping concrete test cylinders be investigated.

Two hundred concrete test cylinders were made in the Research Laboratory of the Tennessee Highway Department and divided into 5 series of 40 cylinders each. Each series was tested with a different type of cap and contained 20 cylinders designed for 3500 lb. per sq. in. and 20 cylinders designed for 2000 lb. per sq. in. The 3500-lb. cylinders were made in the proportions of 1:1.98:3.34, dry rodded, with a water-cement ratio of 0.75 and the 2000-lb. cylinders were made in the proportions of 1:2.58:3.99, dry rodded, with a water-cement ratio of 0.85. At least 25 cylinders were made each day, five of which were capped in accordance with each series, thus eliminating the possibility of errors in concrete manufacture. Table I shows the compressive strengths obtained, the diameter of specimens as measured at the time of breaking, and also the type of capping, top and bottom, in each series.

The first series was capped on both ends and tested with standard stiff cement paste in accordance with the Standard Method of Making and Storing Specimens of Concrete in the Field (C 31 - 27).[2] The second series was capped on both ends with a paste of 40-per-cent plaster of Paris (dental plaster) and 60-per-cent normal portland cement. The third series was capped on top with standard stiff cement paste and the bottom of each cylinder was set in a steel casting with an integral retaining ring whose inside diameter was 6.3 in. Sand to a depth of $\frac{3}{4}$ to 1 in. was placed within the ring in the casting and the cylinders placed on the sand for a bottom bearing. At the end of ten operations, the sand was replaced with fresh sand because of the sand grains breaking down under repeated operation. The sand used in these tests was a commercially-produced sand and one which would meet the requirements for concrete sand as set forth in the Society's Tentative Specifications for Concrete Aggregates (C 33 - 28T). The fourth series was capped on top with standard stiff cement paste and the inside diameter of the ring, which contained the sand for the bottom bearing of the cylinder, was increased to 6.7 in. The fifth, and last series, also was capped on top with a standard stiff cement paste, but the retaining ring of the bottom sand bearing was increased to 8.5 in. inside diameter.

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[1] **District Engineer, National Sand and Gravel Assn., St. Louis, Mo.**

[2] **1927 Book of A.S.T.M. Standards, Part II, p. 108.**

TABLE I.—RESULTS OF COMPRESSION TESTS ON CONCRETE CYLINDERS USING VARIOUS TYPES OF CAPPING.

TOP CAP									
Standard Stiff Cement Paste		40-per-cent Plaster of Paris, 60-per-cent Cement		Standard Stiff Cement Paste		Standard Stiff Cement Paste		Standard Stiff Cement Paste	
BOTTOM CAP									
Standard Stiff Cement Paste		40-per-cent Plaster of Paris, 60-per-cent Cement		Confined Sand Bearing, Ring Diameter 6.3 in. inside		Medium Confined Sand Bearing, Ring Diameter 6.7 in. inside		Loose Sand Bearing, Ring Diameter 8.5 in. inside	
Compressive Strength, lb. per sq. in.	Cylinder Diameter, in.	Compressive Strength, lb. per sq. in.	Cylinder Diameter, in.	Compressive Strength, lb. per sq. in.	Cylinder Diameter, in.	Compressive Strength, lb. per sq. in.	Cylinder Diameter, in.	Compressive Strength, lb. per sq. in.	Cylinder Diameter, in.
MIX, 1:1.98:3.34; WATER-CEMENT RATIO, 0.75; DESIGNED FOR 3500 LB. PER SQ. IN. COMPRESSIVE STRENGTH									
3389	6.02	2859	6.00	2985	5.99	2343	6.03	1759	6.00
4045	6.03	3157	6.00	3566	6.01	3130	6.02	1806	6.01
3953	6.01	3385	6.01	3197	6.02	2740	6.01	1517	6.00
2702	6.01	3656	6.01	3390	6.01	2962	6.02	1721	6.00
2470	6.01	2813	6.01	3437	6.00	2405	6.03	2085	6.00
2765	6.00	2803	6.01	3299	6.00	2831	6.01	1672	6.01
2964	6.01	2532	6.02	3580	6.01	3321	6.01	1581	5.99
3130	6.02	3371	6.02	2761	6.00	2439	6.00	1735	6.00
3550	6.02	3221	6.00	3301	6.02	2681	6.02	1914	6.00
4271	6.01	3313	6.00	3305	6.02	2361	6.01	2246	6.02
3799	6.03	3767	6.00	4094	6.00	2876	6.02	2336	6.00
3782	6.00	3568	6.03	2913	6.02	2742	6.02	1740	6.03
3731	6.00	4023	6.01	3867	6.02	3028	6.02	1980	6.01
3469	6.01	3185	6.00	3004	6.01	2830	6.00	1845	6.00
4051	6.02	3594	6.02	3205	6.01	2936	6.00	1790	6.01
3597	6.01	3827	6.02	3269	6.02	2631	6.02	1818	6.00
3622	6.02	3657	6.02	3391	6.01	2826	6.00	1788	6.01
3398	6.00	3668	6.02	3797	6.01	2559	5.99	1812	6.01
3526	6.02	3747	6.02	3381	6.00	3158	6.00	2072	6.02
3373	6.02	4235	6.01	3520	5.99	3069	6.01	2053	6.01
MIX, 1:2.58:3.99; WATER-CEMENT RATIO, 0.85; DESIGNED FOR 2000 LB. PER SQ. IN. COMPRESSIVE STRENGTH									
1925	6.00	1964	6.01	2225	6.01	2157	6.01	1633	6.00
1814	6.02	2203	6.00	1912	6.00	1787	6.00	1632	6.00
1807	6.01	1705	6.00	2038	6.00	2089	6.02	1551	6.02
1884	6.01	2331	6.00	2190	6.01	2005	6.00	1681	6.00
1983	6.01	2010	6.00	2126	6.00	1537	6.00	1387	6.00
2364	6.01	2122	6.00	1862	6.00	2044	6.00	1272	6.00
2345	6.01	1858	6.01	1863	6.00	1592	6.02	1365	6.01
1993	6.02	1776	6.01	1776	6.02	2074	6.01	1621	6.02
2062	6.03	2259	6.02	1911	6.02	2024	6.01	1693	6.01
2502	6.00	2352	6.02	2145	6.00	1840	6.02	1582	6.03
2510	6.01	2225	6.02	2218	6.02	1904	6.01	1417	6.01
2142	6.02	2404	6.01	2174	6.01	1911	6.03	1773	6.01
2043	6.01	1913	6.01	1944	6.01	2127	6.03	1407	6.01
2655	6.01	2472	6.00	2423	6.00	1731	6.01	1300	6.02
2559	6.01	2199	6.02	1862	6.00	1973	6.02	1991	6.00
2427	6.01	2433	6.02	2342	6.02	1983	6.01	1450	6.00
1843	6.01	2057	6.00	1944	6.01	1520	6.01	1420	6.00
1981	6.01	2054	6.00	1897	6.02	1634	6.01	1302	6.01
2010	6.00	1898	6.00	1780	5.99	1624	6.00	1272	6.01
1915	6.02	1959	6.01	1756	6.01	1657	6.01	1220	6.00

Figure 1 shows the relation between the compressive strengths of concrete cylinders, tested with different types of capping and cylinders tested with the standard cement-paste capping in accordance with the A.S.T.M. Standard Method C 31 - 27. The 0.85 water-cement ratio curve shows a steady decrease in the percentage of strength of cylinders capped with standard stiff-cement paste as the restraint of the sand is decreased. It is apparent that a retaining ring in excess of 6.3 in. inside diameter for cylinders varying from 5.99 in. to 6.03 in. in diameter is not satisfactory. In the case of the 3500-lb. cylinders made with a 0.75 water-cement ratio, the first three series shows a satisfactory percentage of compressive strength on the basis of cylinders capped with standard cement paste. It is evident that additional compressive strength of concrete caused a higher concentration of load and shoved the sand into a cone shape when tested in a retaining ring in excess of 6.3 in. inside diameter. It is also evident that if cylinders whose diameters vary from 5.99 to 6.03 in. are capped on top with either a standard stiff cement paste or a 40:60 paste of plaster of Paris and portland cement, and are placed on sand bearings confined within retaining rings whose inside diameters are not in excess of 6.3 in., the strengths obtained will be well within the limit of error expected in testing procedure.

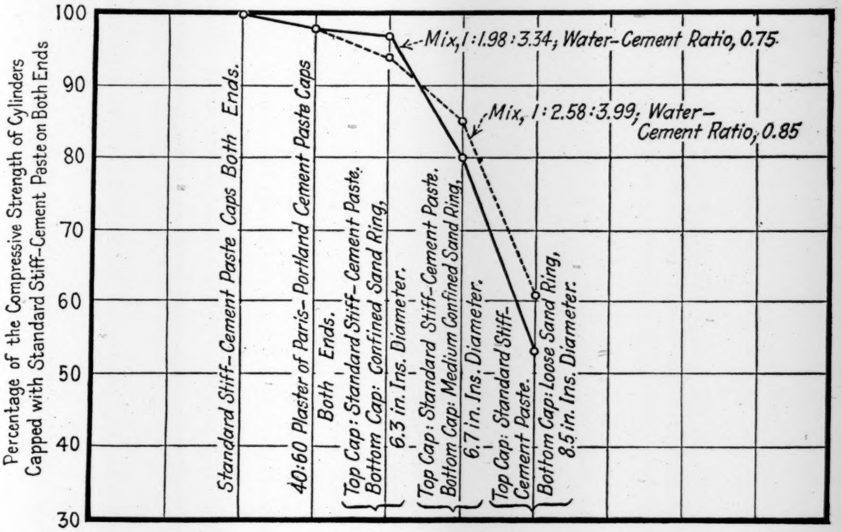

Fig. 1.—Effect of Confined Sand Capping on Concrete Compressive Strength Tests.

The economies of this test procedure using sand cushions may be realized if concrete mixtures are being controlled by cylinder strengths and a considerable number of specimens are being tested. From June 1 to October 1, 1929, the number of concrete test cylinders received by the Tennessee Highway Department was in excess of 100 daily. This necessitates speed of capping and testing, and by eliminating one capping per cylinder, a considerable share of this work may be saved. It has been found that results on concrete test cylinders made in the field and tested with a bottom sand bearing, whose retaining ring has an inside diameter not in excess of 6.3 in., show strengths equal to those tested with caps of the 40:60 plaster of Paris and portland cement paste on both ends and is much more efficient.

APPENDIX II

METHOD OF CAPPING CONCRETE CYLINDERS USING SULFUR COMPOUND

By P. J. Freeman[1]

The method described herein is intended to supplement the present requirement for capping concrete cylinders specified in Section 6 of the Standard Method of Securing Specimens of Hardened Concrete from the Structure (C 42 - 27) of the American Society for Testing Materials.[2] The proposed method conforms with the tentative revision[3] of the Standard Methods of Making and Storing Specimens of Concrete in the Field (C 31 - 27) of the American Society for Testing Materials, Paragraph (b) of Section 6, which reads as follows:

> Where specimens are not capped in the field, they shall be capped before testing in such a manner that the ends are perfectly plane and at right angles to the axis of the cylinder. The material used for capping and the thickness of the cap shall be such that it will not flow under the load.

Concrete cores and cylinders which have irregular ends give the laboratory operator a rather difficult problem. If the strength of the core is greater than the crushing strength of the capping compound used, the indications are that the results obtained for the concrete will be lower than they would be if the specimens were tested after both ends had been ground to smooth planes; that is, the test results do not indicate the true strength of the concrete.

A quick hardening compound and a method of capping has been developed by the Bureau of Tests and Specifications of the Allegheny County Department of Public Works, Pittsburgh, Pa., using a material, which, when poured hot, will adhere to any specimen, whether it be wet or dry. It is possible to remove a specimen from water storage and cap it with this compound without wiping off any of the surface moisture from the ends. The material cools quickly and the specimen may be tested within a few minutes after it arrives in the laboratory.

The compound consists of sulfur and some material such as fire clay, or limestone dust, combined in equal amounts or according to the specific gravity and percentage of voids. Similar material which is used for lining the inside of pickling vats has been found equally satisfactory for capping concrete specimens, and such material may be purchased in the open market. The first cost of such commercial material for a quantity sufficient to cap both ends of a specimen is about eight cents and it may be used two or three times. The actual cost of preparing a small quantity in the laboratory would probably exceed this if the item of labor is included, but the raw materials are very inexpensive.

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[1] Chief Engineer, Bureau of Tests and Specifications, Department of Public Works, Allegheny County, Pittsburgh, Pa.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 118.

[3] *Proceedings*, Am. Soc. Testing Mats. Vol. 29, Part I, p. 864 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 818.

It is necessary to have the concrete specimen in a horizontal position in order to form the cap properly. For that purpose a device not unlike a lathe-bed is used which supports the specimen in movable V-blocks. Such an apparatus is very convenient, although any equipment which will support the specimen in a horizontal position at right angles to a polished plane for producing a smooth surface on the end is satisfactory. Flexible bands are placed around the ends of the cylinder and in contact with the machined plates of the capping sevice. By means of a hand-wheel the position of the end plates is adjusted, The compound is heated until completely fluid, but not hotter, after which it is poured into the flexible bands so as to cap both ends of the cylinder. It would be desirable to have an electrical heating unit which would raise the temperature to a prescribed point, but not above, and thus enable the operator to keep the liquid ready for use at all times, but it is quite satisfactory to use a bucket such as shown in Fig. 1, which can be heated over a gas flame.

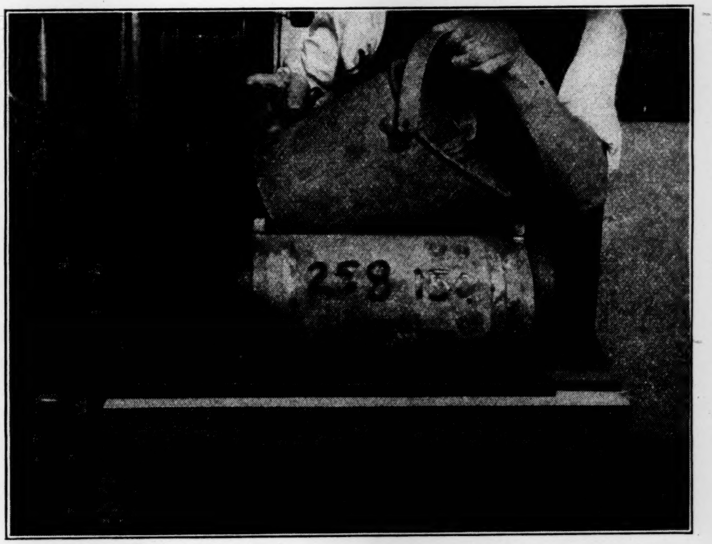
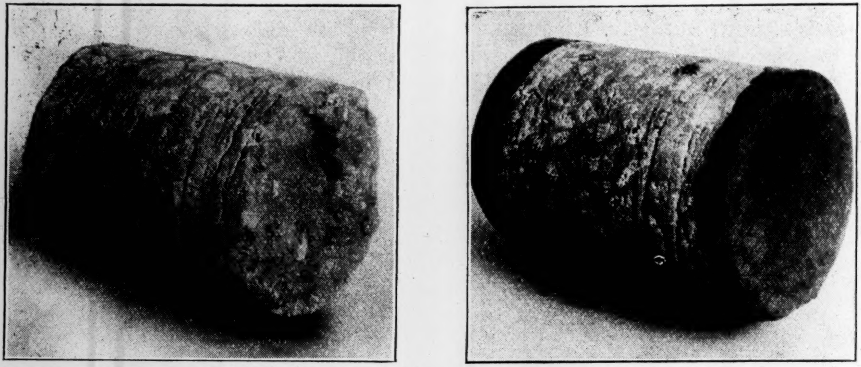


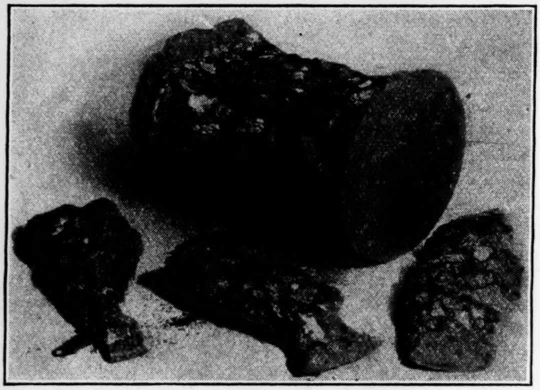
FIG. 1.—Device for Capping Concrete Test Cylinders or Cores.

The appearance of the cap is highly polished, and with the apparatus used, the ends of the cylinder are perfect planes parallel to each other. The crushing strength of properly prepared capping material is at least 8000 lb. per sq. in. when tested as a 2 by 4-in. cylinder. A flat specimen 6 in. in diameter and one or two inches thick has a crushing strength far beyond the capacity of a 200,000 lb. testing machine. It seems reasonable to suppose that such a material when used as a thin cap will develop the full strength of the concrete equal to that which would be obtained if the ends of the cylinder were ground. This material has been in use in the Allegheny County Department of Public Works Laboratory for more than three years, but no definite series of tests has been run to compare results obtained with drilled cores capped in accordance with the A.S.T.M. Standard Method C 31. The appearance of the broken specimen has convinced those using the material that the results are better than can be obtained by any other system of capping with other materials.

The special caps adhere firmly to the concrete but may be broken off with a hammer and re-melted after the specimens are crushed. Eventually a considerable amount of broken concrete will be mixed with the capping material and it will have to be discarded.



(*a*) Core showing irregular end. (*b*) Core after capping with sulfur compound.



(*c*) Broken core with cap.

FIG. 2.—Example of Core, Capped and Broken.

The specimen shown in Fig. 2 was crushed with a plate having a diameter approximately $\frac{1}{2}$ in. less than the diameter of the cap in order to show the behavior of this material. It will be observed that in Fig. 1 (*c*) the plate sheared through the capping material but did not loosen it from the end of the broken pieces.

APPENDIX III

SUGGESTED PROCEDURE FOR TESTING CONCRETE IN WHICH THE AGGREGATE IS MORE THAN ONE-FOURTH THE DIAMETER OF THE CYLINDERS

By F. R. McMillan[1]

The suggested procedure described below, is based on tests made at the Research Laboratory of the Portland Cement Association in which it was found that the strength of the concrete was not materially altered by the removal of large pieces of aggregate from the mass, provided that the removal of this aggregate did not change the consistency of the mix to the extent that an unbalancing occurred, and provided further that in no case was there any aggregate particles left in the test cylinder which were larger than one-fourth the diameter of the cylinder. These tests showed that the greatest change in strength due to removal of the large aggregate resulted from the separation of water from the mixture. This separation was the natural result of the increased fluidity brought about by the removal of the large particles.

In these tests it was found also that if the concrete was restored to its original consistency by the addition of coarse aggregate of the same kind, but of a size not exceeding one-fourth the diameter of the test specimen, the strength was substantially the same as was found for the original mass tested in specimens of a diameter at least four times the maximum size of the aggregate.

Suggested Procedure.—Where the concrete contains coarse aggregate pieces of a size greater than one-fourth the diameter of the cylinder, these should be removed before molding the specimens. This may be accomplished either by picking out by hand or by separating through a screen having this size of opening. If the amount of aggregate so removed is such that the consistency of the remaining mixture is materially altered, the original consistency should be restored by adding coarse aggregate of the same kind, but containing no pieces larger than one-fourth the diameter of the specimen. The aggregate so added should be brought to a surface-moist condition before introducing into the mix to avoid altering the water-cement ratio through absorption. The consistency should be judged by inspection. The condition desired is that the tendency of the mixture to segregate shall be neither greater nor less than in the original mixture.

With the concrete prepared in this manner, specimens should be molded, stored, and tested in the usual manner.

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[1] Director of Research, Portland Cement Association, Chicago, Ill.

DISCUSSION

Mr. H. J. Gilkey[1] (*by letter*).—Since it is not an uncommon practice to use coarse aggregates graded up to 6 or even 10 in. in diameter, the question of what constitutes a proper sampling and testing procedure for such concretes is of current importance. Although Mr. McMillan's paper was offered as a sound and helpful suggestion, the writer questions the wisdom of offering suggestions that go beyond points on which general agreement has been reached, such as, for example, what virtually amounts to a statement that "in so far as the size and amount of coarse aggregate are concerned, *there are no important variations of compressive strength within the water-cement ratio law*."

The writer feels that the present suggestion is especially unfortunate in that it is offered with no hint that there may be other evidence of a contrary nature. Moreover, the conclusion reached, if in error, is on the unsafe side. In the light of the present limited information on strengths of large aggregate concretes, no one can say how unsafe the conclusion may be but there are indications that the "de-cobbled" sample may show an excess strength of 50 per cent or even more. Even smaller uncertainties than this are not comfortable to contemplate in connection with such structures as are now being planned and built.

Because of the importance of the question, the writer proposes to review some of the more recent evidence that has come to his attention and to discuss some of the factors that are involved.

In 1927 as a result of repeated tests in which he found that the strengths of mortars exceeded the strengths of their concretes, Mr. I. E. Burks, then Concrete Technician in charge of the Santeetlah Dam which was being built for the Aluminum Company of America, was instrumental in having cylinders of concretes and mortars made, the maximum size being 36 by 72 in. These were shipped to Washington and tested at the Bureau of Standards.[2] Some of the larger specimens contained aggregate ranging from 2.5 to 10 in. in size. While the results were not wholly conclusive, they were such that Mr.

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[1] Professor of Civil Engineering, University of Colorado, Boulder, Colo.

[2] *Technical News Bulletin*, U. S. Bureau of Standards, January, 1928, p. 5.

Burks is convinced that it is not valid to assume that the cobble concrete has a strength equal to that from which the cobbles have been removed.[1,2] Mr. Burks uses a reduction coefficient applied to the mortar strength.

Results of other tests of cobble concrete made about three years ago in connection with a dam now completed appear in the accompanying Table I. These limited results show an increase of 16.1 per cent in strength as a result of extracting cobbles to the extent of 32 per cent of the total aggregate or 42 per cent of the total coarse aggregate.

T. C. Powers[3] found that by removing successive maximum sizes of particles from 0 to 3 in. grading, the strength increased in regular stages from 1500 lb. per sq. in. for the 0 to 3 in. to 2100 lb. per sq. in. for 0 to $\frac{3}{8}$ in., an increase of 40 per cent.

TABLE I.—RESULTS OF TESTS OF COBBLE CONCRETE.

Specimen	28-Day Compressive Strengths, lb. per sq. in.		
	With Cobbles	Without Cobbles	Increase, per cent
No. 1	1930	2190	....
No. 2	1760	2000	....
No. 3	1910	2320	....
Average	1870	2170	16.1

Specimens: 18 by 36-in. cylinders.

Proportions, measured loose: 1.0 cement : 2.2 sand 0 to No. 4 : 1.8 gravel $\frac{1}{4}$ to 1 in. : 2.4 gravel 1 to $2\frac{1}{2}$ in. : 3.0 cobbles $2\frac{1}{2}$ to 8 in.

Water-Cement Ratio: 1.0.

Over a period of years the writer has been studying the function of aggregate in concrete. Some of his findings have been previously published and discussed.[4] He has since made several check series and has scanned work of others on the subject. Without exception succeeding series confirm previous findings that the aggregate is an extremely influencing factor. No attempt is made to give findings from any but the last of the tests that have a bearing on the subject.

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[1] I. E. Burks, "Concreting Methods at Chute a Caron Dam," *Proceedings*, Am. Concrete Inst., February, 1930, pp. 353–357.

[2] H. J. Gilkey, Discussion, *Proceedings*, Am. Concrete Inst., June, 1930, pp. 883–886.

[3] T. C. Powers, "Concrete Studies at the Bull Run Dam," *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 390 (1929).

[4] H. J. Gilkey with discussion by H. F. Gonnerman, G. M. Williams and others, *Proceedings*, Am. Concrete Inst., Vol. XXIII, pp. 363–414 (1927).

The accompanying Table II[1] lists results from some tests that were but recently completed.

TABLE II.—COMPARISONS OF CONCRETES AND MORTARS.

Specimens: 6 by 12-in. cylinders.
Aggregate: Crushed granite (screenings and stone).
All mixtures were plastic and workable. Tests were made during the spring of 1930.
Each value represents 1 or 2 tests at 7 days and 2 to 5 tests at 28 days.

Line	Proportion by Weight	Water-Cement Ratio	Slump	Size of Coarse Aggregate	Compressive Strength		Strength Ratios to				Order of Strengths, High to Low		Comparison with Abrams $S = \frac{14000}{7^x}$ (28-day only)		
							The Coarse Aggregate Concrete		The Mortar						
					7 Days	28 Days	7-Day	28-Day	7-Day	28-Day	7-Day	28-Day	Theoretical Strength, lb. per sq. in.	Ratio[a]	Order of Ratios[b]
1	1:2.5:0	0.90	5.3	....	3220	5050	1.23	1.39	1.00	1.00	1	1	2430	2.08	4
2	1:2.5:4	0.90	0.0	¼ to 2	2620	3660	1.00	1.00	0.81	0.72	3	5	2430	1.51	12
3	1:2.5:0	1.00	8.5	....	2830	4650	1.68	1.97	1.00	1.00	2	2	2000	2.32	2
4	1:2.5:4	1.00	0.7	¼to2	1990	3100	1.18	1.31	0.70	0.67	7	8	2000	1.55	10
5	1:2.5:4	1.00	0.5	¼to1	2070	3150	1.23	1.33	0.73	0.68	6	7	2000	1.58	9
6	1:2.5:4	1.00	3.5	1½to2	1685	2360	1.00	1.00	0.59	0.51	9	10	2000	1.18	13
7	1:3:0	1.00	....	....	2250	3830	1.33	1.62	0.80	0.82	4	3	2000	1.92	5
8	1:3:0	1.10	8.8	....	2110	3710	1.38	1.36	1.00	1.00	5	4	1650	2.25	3
9	1:3:5	1.10	1.0	¼to2	1530	2730	1.00	1.00	0.72	0.74	10	9	1650	1.66	6
10	1:3:0	1.20	9.8	....	1730	3280	1.32	1.58	1.00	1.00	8	6	1350	2.43	1
11	1:3:5	1.20	0.9	¼to2	1430	2220	1.09	1.07	0.83	0.68	11	11	1350	1.65	7
12	1:3:5	1.20	0.4	¼to1	1355	2200	1.04	1.06	0.78	0.67	12	12	1350	1.63	8
13	1:3:5	1.20	2.2	1½to2	1310	2070	1.00	1.00	0.76	0.63	13	13	1350	1.54	11

[a] Ratio of actual strength to Abrams strengths for 28-day specimens. It shows relative strength variations within the water-cement ratio law

[b] This column gives the order of strength variation within the Abrams law (numbered from high to low).

The concretes were all entirely workable. While some of the mortars were rather thin (as the slumps indicate) the sand was well graded and held its water unusually well. The mortars were kept well stirred during placement. While those tests were on 6 by 12-in. specimens, parallel and more extensive mortar series were run on 2 by 4-in. specimens over a wider water-cement ratio range. They check the mortar findings from the larger cylinders perfectly.

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[1] In presenting Table II it may be well to anticipate certain arguments that may be launched against the validity of its contents. Previous discussions on this subject may be consulted, such as those of Lyse, *Proceedings*, Am. Concrete Inst., Vol. XXV, pp. 421–426 (1929), Gonnerman, *Proceedings*, Am. Concrete Inst., Vol. XXIII, pp. 399–404 (1927). Mr. Lyse states that mortar starts to segregate badly at a 3 or 4-in. slump and shows curves in which the mortar is much stronger than the concrete, but the extra strength is attributed to segregation as a result of the very fluid mixture that remains after the coarse aggregate is removed. The writer, however, in many other tests finds that stiff mortars, and concretes as well, overrun the water-cement relation even more than do the fluid mixtures. Moreover, Collier, Fig. 3, *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 734 (1930), produces convincing data to show that in his experience the stiffer the workable mixture, the stronger it was at constant water-cement ratio. Thus the writer's reply would be that had these mortars been less fluid the overrun would probably have been greater. All segregation effects are such as to weaken instead of strengthen concretes and mortars with the one exception of actual loss of water. These losses were measured and would have accounted for but a fraction of the strength differences without allowance for any compensation due to weakening in other ways such as by water gain, H. J. Gilkey, "Water Gain and Allied Phenomena," *Engineering News-Record*, February 10, 1927, p. 242; H. J. Gilkey with discussion by H. F. Gonnerman, G. M. Williams and others, *Proceedings*, Am Concrete Inst., Vol. XXIII, pp. 407–414 (1927).

In the present connection it is especially interesting to note the effect of the coarse aggregate grading as indicated on lines 4, 5, 6, and 11, 12, 13. In the normal ¼ to 2 in. grading half of the coarse aggregate was above the 1-in. mesh. While some of the larger aggregate particles were retained on the 1.5-in. sieve, very few of them were in the vicinity of 2 in.

The ultimate strengths, however, tell but part of the story. With all of these tests (and many others) both longitudinal and lateral strains were measured continuously to the ultimate strength.[1] The stress-strain curves show that the internal breakdown starts much earlier for concretes than for mortars and that the larger the coarse aggregate the lower the stress at which deformations start to increase rapidly. This is deemed significant and agrees perfectly with an hypothesis that finds strong support in evidence that is recorded by Dwyer and Bates[2] and also by Collier.[3] The hypothesis is that initial breakdown is mainly due to a slippage between the surfaces of aggregate and paste and for a given quality of paste (as determined by the properties of the cement and the amount of water used), the larger the aggregate particles, the lower is the stress at which appreciable slippages will occur. This statement assumes the

TABLE III.—RESULTS OF TESTS—CEMENT PASTE WITH COBBLES.

Water-cement ratio = 42 per cent by weight (0.63 by loose volume or 4.7 gal. per bag).
Specimens cast in non-leakable cylindrical molds 3.27 in. in diameter.
All poured from a single batch of paste which was kept well stirred.
Aggregate (less than ¼ diameter of mold) added by trial in whatever amount specimen could carry.

Specimen No.	Proportion by Weight	Aggregate		7-Day Compressive Strengths, lb. per sq. in.
		Kind	Size	
1	1:2.51	Gravel	½ to ¾ in.	1400
12	1:2.50	Gravel	½ to ¾ in.	1520
2	1:2.04	Crushed Quartzite	½ to ¾ in.	1700
Average Concrete Strength				1540
Paste Strength 9 Specifications, Nos. 3 to 11 (See Table IV)				3410

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[1] See discussion of paper by C. H. Scholer, p. 632.

[2] H. J. Gilkey, Discussion of paper by J. R. Dwyer and P. H. Bates, "The Relation Between the Strengths of Cements Developed by Mortar Specimens and Concrete Specimens," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 615 (1930).

[3] I. L. Collier, "Variations of Compressive Strength of Concrete Within the Water-Cement Ratio Law," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 731 (1930).

grading of the aggregate to be the only variable to be considered and that the aggregate is a normal one. The secondary actions such as wedging, crumbling of mortar walls or cracking of the aggregate particles are all in the nature of after effects. It is to be presumed that initial slippage starts the train of secondary effects in motion and that it is correct to predict that, in general, the mixtures with the larger aggregates will show the lower ultimate strengths. For weak or special aggregates the fundamental action might be quite different from that suggested. Table III gives the results of some recent 7-day tests of "miniature cobble concrete." This small series of tests was run in connection with matters considered in Table IV (effect of removing excess water from top of specimen), and the three "cobble concrete specimens" were made incidentally. Specimens Nos. 1 to 9 inclusive were poured in three stages in rotation and those containing stone were Nos. 1, 2 and 12 as noted. Specimens Nos. 10 and 11 (paste specimens) were poured together and No. 12 was poured last from the residue of the batch of paste. The stone (soaked for about 15 minutes and surface dried) was worked into the paste. Flawless specimens were obtained. The cement paste, with one-size aggregate in it, is admittedly a freak mixture, but it bears a strong resemblance to cobble concrete.

Lateral strains were measured continuously (until the dial ran out of bounds).[1] The lateral stress-strain diagrams show very clearly the early internal breakdown of the concretes by wedging as a result of probable slippage.

The crushed quartzite specimen was somewhat stronger than either of the gravels and the mixture could not carry quite as much of the crushed stone.

While the mortar specimens were very fluid (but with no uncontrolled water loss, see Table IV) the concrete specimens from the same paste: (*a*) were plastic, (*b*) were free from segregation, (*c*) neither gained nor lost moisture, (*d*) met the maximum size requirement (aggregate not exceeding one-fourth the diameter of specimen), and (*e*) had no flaws and were free from honeycomb.

Yet the mortar or paste matrix gave strengths 2.22 times those of the concrete. The mixtures, while admittedly unusual, meet the water-cement ratio law requirements. If the discrepancy be ascribed to the freakishness of the grading or to the fact that the matrix was paste instead of sand-mortar then it is thereby conceded that the water-cement ratio law does have its exceptions and that the addition of some stones to the paste weakened it. It follows that any unusual grading might introduce a major discrepancy. That being the case, it follows that to assume that large-aggregate concrete will follow the same water-cement strength law as do concretes from smaller aggregate is questionable until the correctness of such an assumption has been convincingly verified by test.

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[1] See discussion of paper by C. H. Scholer, p. 632.

A conclusion in a paper by Gonnerman and Shuman[1] states, "The tests show that such factors as size and grading of the aggregate affect the compressive and tensile strengths and the modulus of rupture of concrete of a given mix and consistency only as they affect the amount of water required to produce the desired consistency. The strength increased with the size of the aggregate and also with the increase in the proportion of coarse to fine so long as the proportions of coarse did not result in an undersanded mix." The statements in the second sentence of this quotation naturally follow from the first sentence, since the water requirement decreases with coarseness of aggregate, but at constant water-cement ratio, the Dwyer and Bates data[2] show an exactly opposite trend that in some instances will not only neutralize but more than offset the effect of the increased amount of water required to maintain a given workability. The Powers,[3] Collier[4] and many other tests lead to the same conclusion. Table II shows several instances in which the finer grading (decreased fineness modulus) more than offsets a 10-per-cent increase in water-cement ratio and in one case a 20-per-cent water handicap is overcome.

In spite of the conclusions that have always been drawn from the tests at the Portland Cement Association Laboratory, the variations that are there obtained within the law appear to be as great as those of any other laboratory, unless Collier's Fig. 1[4] showing the plotted results of Portland Cement Association Series 78, 83 and 85 is decidedly non-representative. Between the two main border lines, in which zone the points are uniformly spaced, the spread is from 40 per cent for the higher-strength mixtures to 100 per cent or more for the weaker mixtures at the right. The depth of zone of from 2000 to 1000 lb. per sq. in. exceeds the total spread for any water-cement ratio in the mixtures of Table II of this discussion.

From such evidence it would appear that the real difference lies not in the question of whether there are large variations within the law, but rather in why such differences exist. Apparently it is contended that such differences are inherent in the material and should not be construed as tending to show that the law itself is not absolute or that there may not be other laws that exercise a modifying influence.

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[1] H. F. Gonnerman and E. C. Shuman, "Compression, Flexure and Tension Tests of Plain Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 550 (1928).

[2] H. J. Gilkey, Discussion of paper by J. R. Dwyer and P. H. Bates, "The Relation Between the Strengths of Cements Developed by Mortar Specimens and Concrete Specimens," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 615 (1930).

[3] T. C. Powers, "Concrete Studies at the Bull Run Dam," *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 388 (1929).

[4] I. L. Collier, "Variations of Compressive Strength of Concrete Within the Water-Cement Ratio Law," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 731 (1930).

The point of view of others is that a *water-cement ratio law* that will permit equal strengths over a 30-per-cent range of water-cement ratio is either an imperfect or an incomplete law. The writer contends that discrepancies of this magnitude do not "just happen" and that attempt should be made to run them down in the interests of a more complete knowledge.

Some of the reasons why many of the carefully conducted and well-controlled series do seem to verify the correctness[1] of the Abrams relation, with spreads much smaller than those of Collier's Fig. 1,[2] are mentioned in connection with the Dwyer and Bates discussion.[3]

In so far as a series parallels the controlling tests from which the Abrams relation was determined, to that extent its results take account of variable gradings, proportions, water-cement ratios and all the other things of which the Abrams equation or curve is but the average or composite result.

Within the range of "usual or practical" concrete mixtures, there is almost no variation in grading as compared with the variation between a mortar and its concrete or between an ordinary concrete and cobble concrete. For a given sand and coarse aggregate a change in grading takes place only as the ratio of coarse to fine is altered. Over the entire range of "usual mixtures" this ratio falls between 1.5 and 2, including all such mixtures as 1:1:2; 1:1½:3; 1:2:3; 1:2:4; 1:2½:4; 1:3:5; 1:3:6; 1:4:8; etc. The upper limit of size is usually 1½ in. While the effect of variation in aggregate-cement ratio, which may range from 3 to 8, or greater, must still be classed among the things that we know but little about, the present indications are that, as a variable, this is much less disturbing than is the grading. Table I and Fig. 3 of the Collier paper[2] and part of the data from gradings B, F and I of the Dwyer-Bates tests[3] point to this conclusion as being proper.

Thus such a series as that of Slater at Lehigh[4] is a true water-cement ratio series since the water-cement ratio is the only one of the recognized major variables that is present to any important extent. This same condition holds for most series that have been run in connection with large projects or as a preliminary step to an investigation. As soon as differences in grading or in types of aggregate are introduced, spreads may be expected to increase (and they do).

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[1] By correctness is meant that plotted results show a very perfect parallelism to the Abrams curve or else that they fall within a narrow zone along a smooth line. It is now recognized that differences in cement and other factors are such that no such relation can be expected to be numerically absolute. Most present day concretes greatly overrun the value $S = \frac{14,000.}{7^x}$

[2] *Loc. cit.*

[3] *Loc. cit.*

[4] W. A. Slater, "Reinforced Concrete Column Investigation," *Proceedings*, Am. Concrete Inst., April, 1930, p. 601, Table 5.

Within the range of *usual concrete practice*, mixtures, the proportions or grading of which differ greatly from those listed, may properly be classed as "freaks." However, this subject of cobbles is a different matter. Compared with usual mixtures cobble concrete *is a freak* and the writer contends that the freakishness may be so important in its effect upon strength that it is unsafe to assume that it follows a law that was derived from "normal mixtures" until the correctness of the assumption has been experimentally verified to the point that warrants its acceptance among "the undisputed facts of concrete."

If it be granted that the best means for exercising testing control over large-aggregate concrete is to remove the larger particles in making the specimens,[1] the question of the validity of Mr. McMillan's supplementary suggestion comes up for consideration. If the removal of the large pieces leaves the mixture too fluid, is it correct to add normal sized coarse aggregate promiscuously to obtain a desired consistency? Unless the writer is mistaken in his premise that altering the grading alters the strength, the procedure is not a proper one. If mixed aggregate (of the same proportions as the sample) were used for thickening, the disturbance, considered in the light of Collier's findings,[2] Table I and Fig. 3, might be proper. Then only the aggregate-cement ratio would be altered. But adding any one size of material (be it coarse or fine) alters the grading. The fact that the error introduced, if coarse aggregate is used, tends to offset the alteration brought about by the removal of the large pieces does not justify the procedure since the compensation is but partial and is wholly indeterminate.

The writer grants that differences between normal concretes and mortars raise questions that are mainly academic, no matter how great the differences may actually be. No one is going to substitute mortar for concrete because of them and it is always possible to test the strengths of such concretes in the same proportions as they are used in structure. Just because the questions are academic (that is, of little interest to the concrete practitioner), however, does not mean that they are unimportant. These differences, if present, are of vital interest in the relationship that they bear to the whole underlying theory of concrete; why it has strength, and why it fails. But when it comes to exterpolating present knowledge to cases that are not susceptible of ready checking, the question assumes importance to the practitioner as well as to the investigator.

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[1] **The writer knows of no better method, providing a proper coefficient be applied to the strength obtained from the specimen, after a reasonable value for the coefficient has been found.**

[2] ***Loc. cit.***

The fact that the laboratory of the Portland Cement Association should report conclusions differing from those of other laboratories seems to be not so much a difference in test results as in interpretation.

Mr. Lyse shows[1] curves of mortar strengths *versus* concretes that show mortar strengths 50 per cent above the strengths of their concretes. These are actual strengths by test. Then a new water-cement ratio is computed by deducting the "segregated water." When the observed strength is plotted against the *new water cement ratio*, the points for the mortars fall to the left of the concretes on the exact prolongation of the concrete-water-cement ratio curve. Since this produces the result desired, it is assumed that the procedure was a valid one.

For example, referring to the series that included the 14-day tests on the 12 by 24-in. specimens alluded to by Mr. McMillan[2,3] and which are evidently the basis for his suggested procedure, Mr. Lyse states:[1] "All molds were sealed so that no leakage occurred and the amount of water which accumulated on the top of the specimens was measured." About the same series,[2,3] Mr. McMillan states: "In these specimens considerable water segregated from the mass and collected at the top. This water was carefully drained off and measured and *the true water-cement ratio for the remaining water was calculated. It is this corrected water-cement ratio that is plotted.*"

The writer is convinced that the procedure outlined fails to take account of what really happens when concrete and mortar specimens are made. Perhaps a very simple experiment will illustrate. Mix a thin mortar, say a 1:2 mixture with a water-cement ratio of 1.00. Pour this in a tight container such as a pint jar that can be sealed. Soon water gathers at the top. It may be $\frac{1}{4}$ in. or more in depth and is clear except for a film of calcium hydroxide on the surface. Keep the jar tightly sealed. Within a few hours (usually two to six but it may be longer in the case of a very thin mixture), the water entirely disappears within the mortar again in case the water-cement ratio does not exceed about 0.85. An excess above this amount may remain on the surface. It represents excess water which should be deducted in computing the effective water-cement ratio.

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[1] T. C. Powers, "Concrete Studies at Bull Run Dam," *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 424 (1929).

[2] F. R. McMillan, "Basic Principles of Concrete Making," pp. 16–17, McGraw-Hill Book Co., Inc., New York City, 1929.

[3] F. R. McMillan, "Basic Principles of Concrete Making," *Engineering News-Record*, April 18, 1929, p. 626.

Repeat the operation but remove the clear water with blotting paper as it collects but be careful not to suck water up from within the mass. Most of the water gathers during the first half hour but for a wet mixture there may be a small accumulation up to three or four hours. Blotting need not be performed oftener than every hour or so and the amount of water removed can be ascertained by successive weighings of the jar. The blotting process may reduce the water-cement ratio to 0.70 or 0.75. The total shrinkage in this case is no greater than it was in the first case in which no water was extracted. This would seem to indicate that the settlement of the solids is not influenced by the removal of the water that has accumulated; in fact it is the settlement that permits the water to accumulate. On the other hand if the reservoir has been drained, no water is available when a few hours later the specimen would again absorb all or part of the water. It seems quite reasonable that the removal might tend to weaken rather than strengthen the specimen. Barring neutralization when the specimens are capped[1] the retarded early curing in the drained specimen should lower instead of raise its strength and if it is felt that a revision must be made, perhaps it ought to be made upward.

Of course the origin of Mr. McMillan's and Mr. Lyse's method lay in their recognition that water-cement ratio and voids-cement ratio are closely allied in that one of the most important factors underlying strength is the relative dispersion of particles for a given cement content. More water expands the mass (increases the water-filled voids) and less contracts it. Removal of water will certainly increase the strength providing the mass is thereby contracted and more intimate contacts are established. In a crude sort of way the jar experiment seems to indicate that the removal of the free water does not contract the mass and later, as this water could re-enter to refill voids (of which there are 25 to 35 per cent) from which the curing processes have extracted water, there is no water available and these spaces simply become air voids instead of water voids. Then, as more water is needed, if these pore spaces are left unreplenished, there may be a sufficient drought to lower the quality.

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[1] If capping with neat cement paste is performed shortly after the top becomes dry, the specimen will get additional water from the cap and the retarded curing may thereby be neutralized. In such a case, which is the usual one, the removal of the water may be expected to have little influence on the properties of the mortar. In the writer's laboratory the capping operation is not performed until the free water has returned to the interior of the specimen, which it does for most mortars and for all concretes.

Using the same water-cement ratio, fill a jar with concrete instead of mortar. It will be observed the shrinkage is less, a layer of water gathers but it is much shallower, and in a relatively short time no free moisture remains. Why this different response? Does a non-absorbent, chemically inert, coarse aggregate act as an accelerator and speed up chemical operations?

In the first place the concrete mass contains about half as much water (and cement) as does the mortar. There is less water to accumulate. The coarse aggregate makes the mass less mobile than the soft easily yielding mortar and instead of a total shrinkage to the top surface there are differential shrinkages throughout the mass. Solids settle away from the under sides of stones that can not follow because they bear upon other stones.[1] Water as it rises is halted beneath flat stone surfaces and it collects in the voids made by the differential settlement just mentioned. Thus the concrete contains less water to be stored and accommodates relatively more of it within the mass. A very slight draft on the shallow surface reservoir exhausts it and the top is left dry hours before the mortar specimen reaches that stage.

In the cases of both the mortar and the concrete, it is evident that the mortar does the shrinking. The concrete only contains about half as much of the shrinking medium and undergoes less than half the total shrinkage on account of the rigid framework that makes it necessary that some of the readjustment be internal as outlined above. Both contain the same relative amounts of water and cement and barring disturbances due to absorption, evaporation, leakage, or intentional extraction, the chemical sequence in the one case should duplicate that in the other. When the equipment used is such that there is some leakage at the base of the mold it is possible that a mixed condition results. In so far as the plastic mortar follows down and becomes more dense by filling up spaces vacated by water, quality of the mortar should be improved. Assuming that some of this action occurs, the next question is whether the densifying effect is local or general. Providing such water does not carry cement out of the mixture (and it does not appear to do so if the base is reasonably tight) the lower layers may be benefited but it is doubtful if the upper reaches are affected. Since the weak part of the specimen is invariably the top[1] the net effect on strength is probably negligible.[2]

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[1] H. J. Gilkey, "Water Gain and Allied Phenomena," *Engineering News-Record*, February 10, 1927, p. 242.

[2] For years the writer has made it a practice to weigh the empty mold before filling, the filled mold, as soon as the concrete is placed and to reweigh the filled mold just prior to capping, after all free water has disappeared at both top and bottom. The leakage and evaporation losses are always insufficient to account for differences between mortars and concretes even if it be assumed that the entire loss is effective for increasing the mean density of the mass (lowering the water-cement ratio). Some of these matters were discussed by Mr. Gonnerman and the writer in 1927.

Specific results may be of interest. Two batches of 1:2.5 standard sand mortar were prepared as suggested. The water-cement ratio was 1.00. After about 4.5 hours there was no more water to be drawn off in the comparison jar. Most of the settlement and water extraction took place within the first hour. These were intended to be the fluffiest or loosest possible mixtures and care was exercised not to jar or agitate the mortars after the first thorough mixing and shaking. There was little change in status after 5 or 6 hours. At 22 hours the water still on top of the mortar in the first jar was drawn off and measured. The results for both batches were as follows:

1. The excess water still on top in the first jar was such as to reduce its water-cement ratio from 1.00 to 0.87. This was a 13 per cent reduction which would raise the estimated 28-day strength 570 lb. per sq. in. or 28.5 per cent.

2. The water drawn off from the second jar was such as to reduce its water-cement ratio to 0.74, exactly twice the decrease of the first. The estimated strength increase was 1330 lb. per sq. in. or 66.5 per cent.

From the above it is apparent that the author's method would have introduced a 26 per cent change in water-cement ratio in attempting to correct for 13 per cent of "excess" water.

In terms of strengths the change introduced would have been 66.5 per cent to make a 28.5-per-cent correction, leaving a net error of 38 per cent. Had the water ratio been 0.87, a 13-per-cent error in water-cement ratio or 30 per cent in strength would have been introduced when actually no correction was needed.

Other tests were made on neat cement. At a water-cement ratio of 1.00, the water remaining at the end of 22 hours gave a revised water-cement ratio of 0.845. The difference from the 0.87 of the sand mortar is due no doubt to the difference in void content and overall dimensions which factors control the amount of internal storage.

Tests on neat cement having a water ratio of 0.63 (42 per cent by weight) showed a reduction of 11 per cent in water-cement ratio or the equivalent of a 15 per cent fictitious increase in strength, accomplished by the removal of water with the blotters. The water all returned to the interior of the unblotted specimens and no correction at all should have been made.

In the foregoing discussion it has been implied that the strength of the specimen made would not be increased by the removal of water that would have returned to the interior of the specimen. It was also concluded that the removal would not weaken the specimen appreciably if it was capped and stored in the usual manner.

As a check on these tentative conclusions, the neat cement specimens mentioned above (42 per cent water by weight, water-cement ratio 0.63) were capped at 35 hours after making and immersed at a total age of 46 hours (2 days).[1] All were tested at 7 days.[2] Table IV gives the results of the strength tests. See details of mixture in connection with Table III.

From Table IV it is evident that the blotting off of the excess water had no effect on strength that could be detected after 5 days' immersion. Specimens were weighed just prior to immersion and again just prior to test. Habitually specimens show a slight gain in weight from moist storage. In this case those from which water had been removed gained several grams more weight in the course of the 5-day storage than did the others. In other words, they simply recovered their water at the earliest opportunity.

TABLE IV.—SHOWING EFFECT OF REMOVING EXCESS WATER.

Specimen	7-Day Compressive Strength, lb. per sq. in.	
	Blotted	Not Blotted
Nos. 3, 4	3590	3570
Nos. 5, 6	3150	3510
Nos. 7, 8	3530	3470
Nos. 9, 10	3330	3100
No. 11	....	3450
Average	3400	3420

The foregoing discussion should go far to show why Mr. McMillan should have reached a conclusion that would permit him to make a suggestion so completely at variance with the findings of other investigators. As each successive size of coarse aggregate was removed from the sample it became more fluid and his water-cement ratio correction became greater. His net result seems to indicate that he found the effect of grading to be almost exactly equal to the assumed effect of water, since they just compensated one another.

The writer is not an advocate of the non-use of cobbles or other large-size aggregate in massive concrete construction. He merely contends that it is as important to know that the concrete as placed approximates the strength desired. If cobbles weaken the concrete that fact should be known and enough extra cement should be added to offset the weakening effect.

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[1] It will be noted that the delayed capping and storing makes a worse condition for the blotted specimens since any initial drought, from the blotting, was given a longer time in which to retard normal curing.

[2] The 7-day test age was also more severe than would have been a later test age, since any early weakening would have had less time for recovery.

Mr. McMillan's suggestion opens up one of the most important of the unsettled concrete questions of the day. It has many angles to it but probably most important of all is the fact that many large dams are being built and the largest of them all is soon to be started. Recent unfortunate events have re-focussed attention upon the great need for ample safety in these structures. It seems to the writer that no phase of concrete is more urgently in need of a thorough overhauling than this matter of grading in the coarser ranges. When such an investigation is undertaken, consideration will need to be given to possible temperature effects on the curing process and to shrinkage or initial stresses whenever results from large specimens are to be compared with those from small ones.

APPENDIX IV

ABRASION OF AGGREGATES

By F. H. Jackson[1]

The Problem.—The problem assigned to the author by Committee C-9 was to assemble all available data showing what relations if any exist between the strength and resistance to wear of crushed-stone and gravel concrete and the results of abrasion tests on the coarse aggregates employed, that is, the standard Deval abrasion test in the case of crushed stone and the modified Deval abrasion test in the case of gravel.

Sources of Information.—The following sources of information have been used in the discussion:

1. H. R. Thomas and G. A. Parkinson, "Effect of Physical Properties of Stone Used as Coarse Aggregate on the Wear and Compressive Strength of Concrete," *Bulletin No. 2814*, University of Texas, April 8, 1928.

2. C. H. Scholer and Harold Allen, "Wear Tests of Concrete," *Bulletin No. 20*, Kansas State Agricultural College, February 15, 1928.

3. F. H. Jackson and J. T. Pauls, "Accelerated Wear Tests of Concrete Pavements," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 864 (1924).

4. A. T. Goldbeck, "Further Tests on Crushed-Stone and Gravel Concrete," *The Crushed Stone Journal*, Vol. 5, No. 5, June, 1929.

5. W. T. Kellermann, "The Effect of Type and Gradation of Coarse Aggregate upon the Strength of Concrete," *Public Roads*, June, 1929.

6. Data from unpublished report of the Portland Cement Association, used by permission.

In each of the above mentioned reports, data are given from which information may be obtained regarding the effect of the physical properties of the coarse aggregate, as measured by the abrasion test, on the crushing strength of the concrete. In certain cases, data on flexural as well as compressive strength are given, while in still other cases the effect of the quality of the aggregate on the resistance of the concrete to wear is also studied. No attempt is made in this report to describe either the materials or test procedure employed in each case. The discussion will be confined to a study of the results secured and the reader is referred to the individual reports for further details. It is of course understood that although the strengths obtained by various laboratories are not directly comparable, a comparison of the quality of the concrete with the quality of the aggregate is justified in each case because of the care used to eliminate the effect of other variables on the quality of the concrete. Attention is called to the fact that a complete report covering the tests made in the laboratory of the Portland Cement Association, and which is referred to in reference No. 6 above, will be published by the association in the near future. The courtesy of the association in releasing the data here given is appreciated. A summary of the data reviewed, in so far as it applies to this particular problem, is indicated in graphical form in order to facilitate ease of comparison. A study of the several relationships follows:

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[1] Senior Engineer of Tests, U. S. Bureau of Public Roads, Washington, D. C.

Relation Between Crushing Strength of Concrete and Abrasion Loss on Aggregate.—Data on relation between crushing strength of aggregate and abrasion

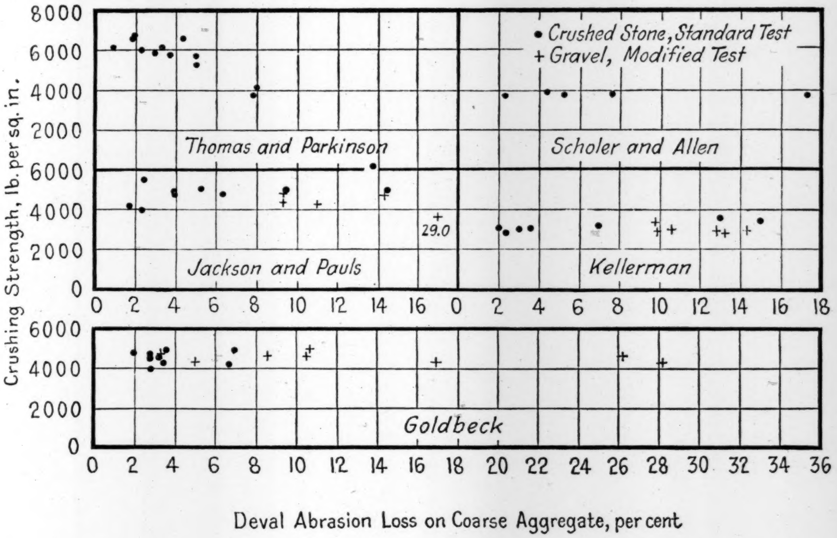

FIG. 1.—Relation Between Crushing Strength of Concrete and Abrasion Loss on Aggregate.

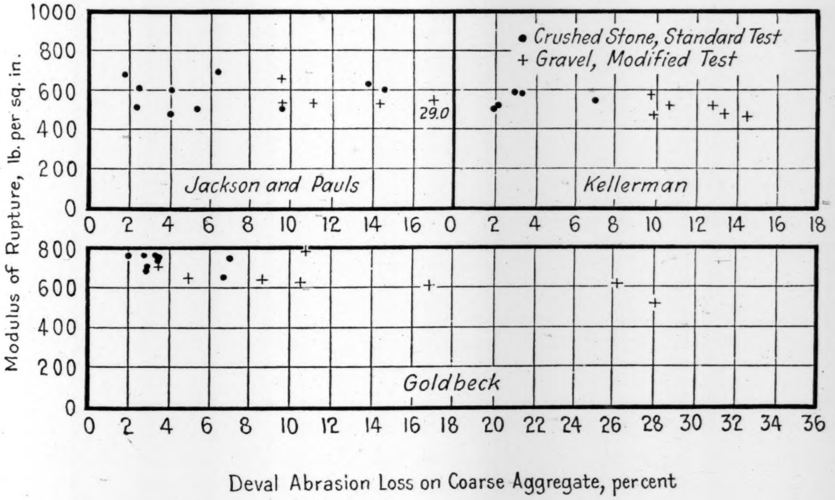

FIG. 2.—Relation Between Flexural Strength of Concrete and Abrasion Loss on Coarse Aggregate.

loss on aggregate are given in Fig. 1 and cover the results secured in five separate investigations. In Figs. 4 and 5 similar data covering the unpublished work of the Portland Cement Association are also given. An inspection of the charts indicates that in only one case, that of Thomas and Parkinson, does there appear to be any indication that the crushing strength of the concrete is affected materially by the resistance of the coarse aggregate to abrasion. This applies both to crushed stone and gravel and includes values for abrasion loss running well beyond the usually accepted limits.

Relation Between Flexural Strength of Concrete and Abrasion Loss on Coarse Aggregate.—Data covering the work of three investigations are given in Fig. 2. In the case of the test reported by Goldbeck, the proportions of cement to aggregates were adjusted so as to give approximately the same cement content for all materials. In the case of the other two investigations, the comparisons were made on the basis of the same apparent volume of cement to aggregate for all materials.

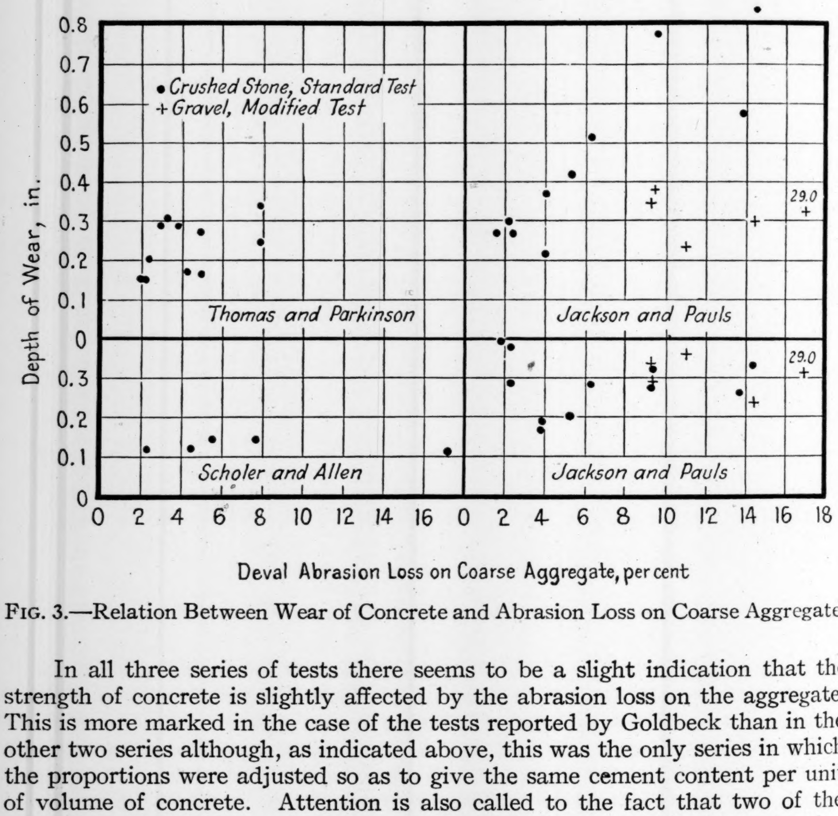

FIG. 3.—Relation Between Wear of Concrete and Abrasion Loss on Coarse Aggregate.

In all three series of tests there seems to be a slight indication that the strength of concrete is slightly affected by the abrasion loss on the aggregate. This is more marked in the case of the tests reported by Goldbeck than in the other two series although, as indicated above, this was the only series in which the proportions were adjusted so as to give the same cement content per unit of volume of concrete. Attention is also called to the fact that two of the gravels used in the test reported by Goldbeck had exceptionally high abrasion losses.

Relation Between Wear of Concrete and Abrasion Loss on Coarse Aggregate.—Data on relation of wear of concrete and abrasion loss of aggregate are tabulated in Figs. 3, 6 and 7. Figure 3 gives the results of tests made in two laboratories using the Talbot-Jones method as well as the results of the special wear tests on concrete spheres as employed by Scholer and Allen and in the Circular Track

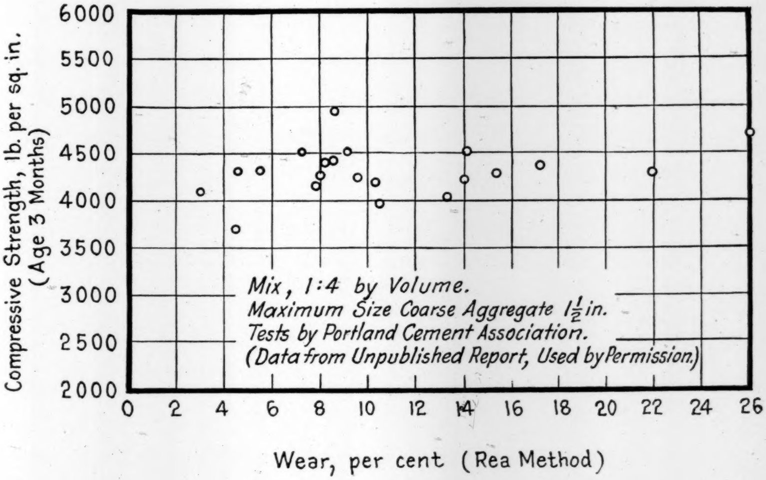

FIG. 4.—Relation Between Crushing Strength of Concrete and Abrasion Loss on Gravel.

Mix, 1:4 by volume.
Maximum size coarse aggregate, $1\frac{1}{2}$ in.
Tests by Portland Cement Association.
(Data from unpublished report—used by permission.)

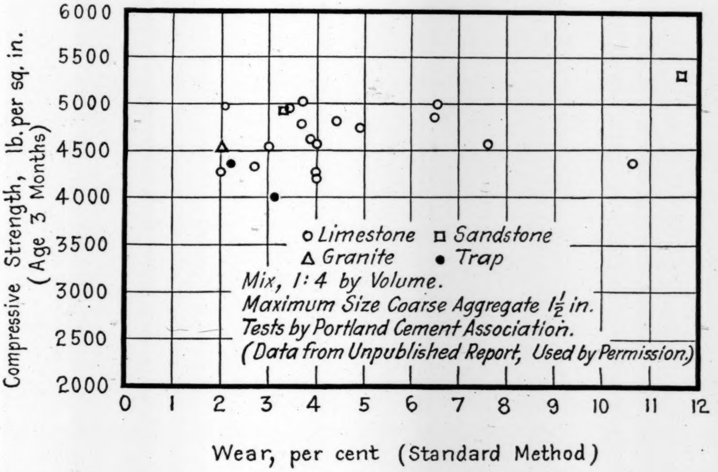

FIG. 5.—Relation Between Crushing Strength of Concrete and Abrasion Loss on Stone.

Mix, 1:4 by volume.
Maximum size coarse aggregate, $1\frac{1}{2}$ in.
Tests by Portland Cement Association.
(Data from unpublished report—used by permission.)

Wear Tests at Arlington reported by Jackson and Pauls. In the latter case the depth of the wear plotted corresponds to the actual depth of the wear in the circular track pavement after approximately 50,000 passages of a solid rubber-tired truck wheel loaded to 3000 lb., equipped with skid chains and traveling at the rate of 22 miles per hour. In Figs. 6 and 7 the relation between the Talbot-Jones wear test and the abrasion loss on aggregates as determined by

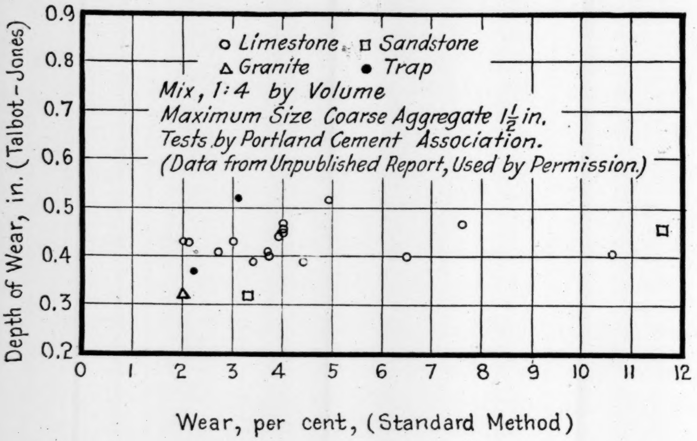

FIG. 6.—Relation Between Abrasion Loss on Stone and Talbot-Jones Wear Test.
Mix, 1:4 by volume.
Maximum size coarse aggregate, 1½ in.
Tests by Portland Cement Association.
(Data from unpublished report—used by permission.)

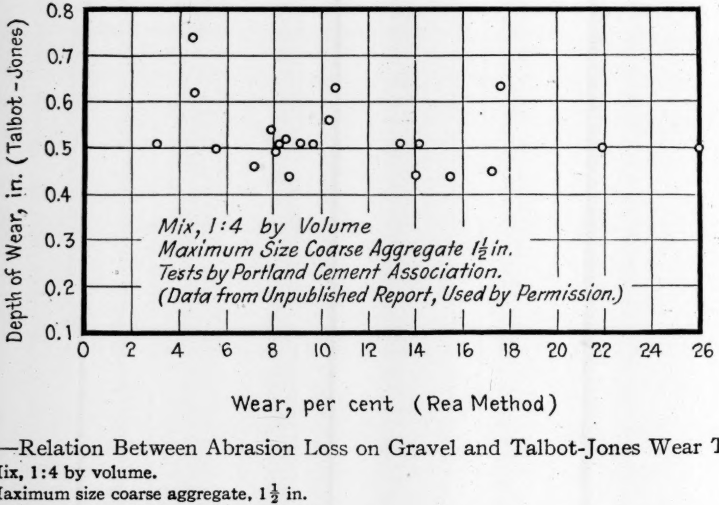

FIG. 7.—Relation Between Abrasion Loss on Gravel and Talbot-Jones Wear Test
Mix, 1:4 by volume.
Maximum size coarse aggregate, 1½ in.
Tests by Portland Cement Association.
(Data from unpublished report—used by permission.)

the Portland Cement Association is given. The results for various types of stone are given in Fig. 6 and the corresponding results on gravel in Fig. 7.

Reference to the data fails to indicate any relation between the results of the Talbot-Jones wear test and the abrasion loss on aggregates with the possible exception of the tests made by Thomas and Parkinson in the University of Texas Laboratory, which indicate slightly higher concrete wear in the case of stone having high abrasion loss. The special wear test conducted by Scholer and Allen at the Kansas State Agricultural College likewise indicates that concrete wear is not affected by abrasion loss on the aggregate. In the case of the Circular Track Wear Test described by Jacksan and Pauls it will be observed that crushed-stone concrete containing aggregate having high abrasion loss shows relatively high concrete wear. In fact, there seems to be a fairly definite relation between abrasion loss on stone and the depth of the wear of the concrete. There does not, however, appear to be a corresponding relationship in the case of the gravel concrete. The Portland Cement Association tests also indicate that there is no relation between abrasion loss on either crushed stone or gravel and the depth of wear as indicated by the Talbot-Jones wear test.

Conclusions.—The following conclusions are drawn as the result of a study of the available data:

1. That within the ranges of abrasion loss studied, the crushing strength of concrete is not affected by the quality of the coarse aggregate as measured by the standard Deval abrasion test.

2. That the data available are insufficient to warrant any definite conclusion as to the effect of abrasion loss of aggregate on the transverse strength of concrete. Additional studies are recommended.

3. That within the range of the abrasion losses studied, the resistance of concrete to wear as measured by the Talbot-Jones wear test is not affected by abrasion loss on aggregate.

APPENDIX V

ONE-YEAR TESTS ON THE EFFECT OF DUST-COATED STONE ON THE PROPERTIES OF CONCRETE

By A. T. Goldbeck[1]

In connection with the annual report of Committee C-9 for 1929[2] the results of tests to determine the effect of dust-coated stone on the properties of concrete were published. In these tests three different types of coarse aggregate were employed, a limestone, a trap rock and a sample of gneiss. Concrete beams and cylinders were made in proportions of 1:2:3 by loose volume and the coarse aggregate was previously dampened and thoroughly mixed with given percentages of fine stone dust made of the stone used in the tests so that the coarse aggregate was thoroughly coated with a pasty coating before it was made up into concrete.

The strength tests were made at 28 days and also a series wear of tests were made on the troweled surface of the concrete to determine if the dust had a tendency to create a weak surface layer which might wear rapidly. The indications from these preliminary tests as stated in the above-mentioned report were as follows:

> *1.* That a decrease in modulus of rupture due to the dust is from 1 to 1.5 per cent for each increase of 1 per cent in dust (percentage based on weight of stone).
>
> *2.* That a decrease in crushing strength is from 0 to 2 per cent for each increase of 1 per cent in dust up to a limit of 5.7 per cent of dust used in these tests.
>
> *3.* That dust up to 5.7 per cent by weight of stone did not cause any serious decrease in resistance to wear.

The 28-day tests, therefore, showed that the dust-coated stone of the varieties used did not have any particularly bad effect on the properties of concrete, even when the dust extended up to 5.7 per cent of the weight of the stone. Ordinarily a commercially produced stone which is badly coated will not have more than 1.25 per cent of dust by weight, provided the dust is uniformly distributed throughout the mass. Of course, there is the possibility of a higher percentage of dust accumulating in layers, especially after a heavy rain.

The question naturally arises as to whether the dust may not cause trouble at longer periods even though no bad effects are noticed at the age of 28 days. To investigate this possibility, concrete specimens were made up for testing at the age of one year. As in the case of the 28-day specimens, the stone was previously coated with dust by mixing the moist stone with dust ground to a fineness, as follows:

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[1] Director, Bureau of Engineering, National Crushed Stone Assn., Washington, D. C.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 301 (1929).

FINENESS OF STONE DUST NO. 18

Total retained on a No. 100 sieve	4 per cent
" " " " " 200 "	15 "

In the present series limestone only was used, having the following gradation:

1 to ¼-in	60 per cent
¼ to No. 4 mesh	35 "
No. 4 to 0	5 "

The proportions were 1:2:3 by loose volume. The sand was Potomac river sand graded as follows:

POTOMAC RIVER SAND GRADATION

Retained on a No. 4 sieve	3 per cent
" " " " 10 "	19 "
" " " " 20 "	31 "
" " " " 30 "	41 "
" " " " 50 "	75 "
" " " " 100 "	93 "
" " " " 200 "	96 "
Silt and clay	2.7 "

The mixing was performed by the use of shovels and was continued until the concrete appeared to be thoroughly mixed. This generally required four movements of the pile after adding the water.

In Table I are given further data with regard to the concrete:

TABLE I.—DATA ON CONCRETE MIXTURES USED TO DETERMINE EFFECT OF DUST-COATED STONE ON THE STRENGTH OF CONCRETE AT AGE OF ONE YEAR.

Test	Dust in Stone, per cent	Flow	Water-Cement Ratio	Weight of Concrete per cubic foot, lb.
No. 18-A2	0.7	194	0.89	147.8
No. 18-B2	1.7	200	0.93	149.6
No. 18-C2	2.2	198	0.94	148.2
No. 18-D2	3.7	197	0.94	148.2
No. 18-E2	5.7	198	0.96	148.6
No. 18-F2	0.7	162	0.85	148.8
No. 18-G2	1.7	166	0.86	148.8
No. 18-H2	2.2	162	0.86	148.4
No. 18-I2	3.7	160	0.87	148.2
No. 18-K2	5.7	163	0.90	148.8

Figure 1 shows the strength results obtained with concrete of medium and also of comparatively wet consistency. Referring to this figure, it will be noted that as the percentage of dust increased, it was necessary to somewhat increase the water-cement ratio in order to maintain the desired consistency. Notwithstanding this fact, however, there seems to be no marked decrease in strength either in compression or cross-bending. The compressive strength seems to be slightly more affected than the cross-bending strength. In any event, the decrease in strength is not of sufficient magnitude to affect the design of concrete structures. The general conclusion which may be reached from these tests is that stone dust up to 5.7 per cent of the weight of stone used does not seem to have any particular effect on the properties of the concrete.

It should not be concluded, as the result of these tests, that in no case does stone dust produce harmful results in concrete. There are well authenticated cases of dust interfering with the bond between the coarse aggregate and the mortar. Evidently there are certain types of stones to which the dust clings tenaciously, notwithstanding the scouring action which takes place in the mixing process.

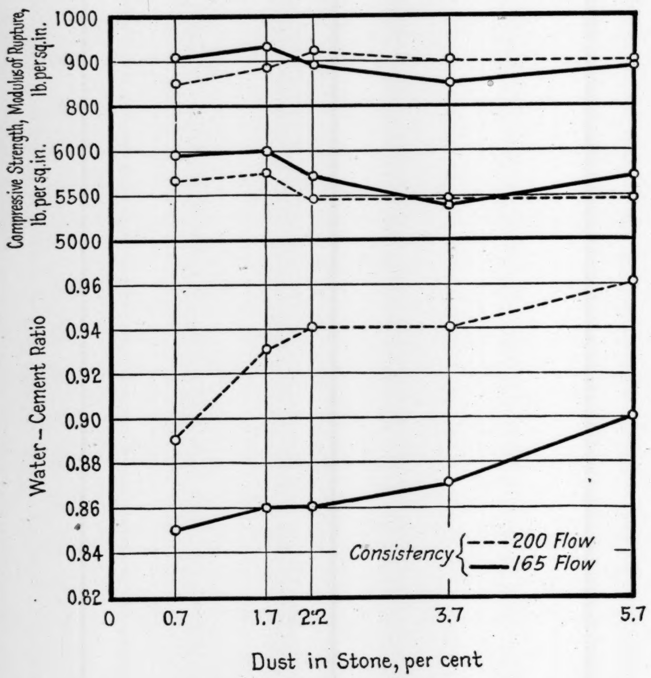

FIG. 1.—Effect of Dust-Coated Stone on Properties of Concrete.

Other stones, such as typified by that used in the present tests, are scoured during the mixing of the concrete and no bad effects are produced. Stones of this character, containing coatings composed of rock dust alone which is easily displaced, probably are never harmful. Other stones from which the dust coating is not easily removed may produce bad effects. Each case is an individual one which should be judged on its merits.

APPENDIX VI

REPORT OF SECTION ON RELATION BETWEEN THE ABRASION LOSS ON BLAST-FURNACE SLAG AND ITS CONCRETE-MAKING PROPERTIES

The question of whether the abrasion loss of blast-furnace slag has any relation to its concrete-making qualities has been raised by many engineers and specification writers who have had occasion to specify this material. Coupled with this question has been the one as to whether the unit weight of slag is a satisfactory measure of its quality for use in concrete. The efforts of this section have been: (1) to study the results of all existing research work bearing on this subject, and (2) to study slags from a sufficient number of individual sources having a sufficient range in weight and abrasion loss to be entirely representative of the product as commercially produced. The committee has had in mind particularly the presentation of a report sufficiently complete and comprehensive to justify definite conclusions as to the specification limitations which should be placed on slag to insure the proper quality for use in concrete. The data presented in this report are naturally divided into two sections, (1) data developed previous to the time this subject was assigned to the section, and (2) data developed by the section during its study of the subject. The first includes: "Cooperative Tests of Slag by Seventeen Laboratories," January and February, 1928; Report of Tests on Slag and Slag Concrete, by Ohio Highway Department, July, 1928; and "Blast-Furnace Slag as an Aggregate in Concrete" (U.S. Bureau of Roads Tests), by Raymond Harsch.[1]

PREVIOUS INVESTIGATIONS

Tests of Slag by Seventeen Laboratories:

In the winter of 1927–1928, 17 laboratories cooperated in a series of tests for weight per cubic foot and abrasion losses of four commercial slags selected from as many different plants in Ohio. The object of the tests was threefold: (1) to determine the relation between weight per cubic foot of slag and the losses shown in the Standard Deval and modified Deval abrasion tests; (2) to obtain information on the possibility of duplicating results on the same slag in different laboratories, using standard methods throughout; and (3) to ascertain the possibility of checking results on duplicate samples of slag when tested by the same laboratory. Twenty-four samples were tested from each plant, 7 of the 17 laboratories running double samples. Every precaution was taken to insure uniformity of the samples, which were selected by the late Mr. A. S. Rea[1] from each plant and placed in sacks under his supervision. The sacks were identified only by letter, 17 from the first plant being labelled slag "A" and 7 designated slag "E". The same procedure was followed for slags B, C and D, with their respective duplicates, slags F, G and H, and the sacks were immediately shipped to the various laboratories. The results of the tests on each slag are given in Table I. The columns headed "Variation, per cent" represent the variation of the particular result from the average of test results obtained by all laboratories on the same material.[2]

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 255 (1923).

Ohio State Highway Department Tests:

At the time of the collection of samples for the cooperative tests outlined above, it was considered desirable to supplement them with concrete tests in order to show the relation of weight and abrasion loss to the concrete-making properties of the aggregate, using as coarse aggregate the 4 slags from the sources selected. One lighter slag (slag I) was also included to show the effect of light weight slag. The concrete tests were made in two mixes, one containing 6.7 sacks of cement per cubic yard and the other 6.4 sacks per cubic yard. The proportions were adjusted to secure the prescribed cement contents, resulting in the following mixes, measured by dry, loose volumes of aggregates:

	6.7-SACK MIX	6.4-SACK MIX
Slag A	1:2.03:3.05	1:2.23:3.35
Slag B	1:2.03:3.05	1:2.23:3.35
Slag C	1:2.02:3.03	1:2.22:3.33
Slag D	1:2.00:3.00	1:2.20:3.30
Slag I	1:2.04:3.06	1:2.24:3.36

The concrete was hand-mixed and molded into 6 by 12-in. cylinders for compression tests and 6 by 8 by 30-in. beams and 6 by 6 by 40-in. beams for flexure tests. For the 6 by 8 by 30-in. beams, the tests were made with the cantilever machine described by H. F. Clemmer in *Public Roads* for May, 1926,[3] while the cantilever machine of the Ohio State Highway Department was used for the 6 by 6 by 40-in. beams. The Clemmer machine has a wood extension arm and the load is applied with lead weights, while the Ohio machine has a steel extension arm and the load is applied through a worm-and-gear arrangement.

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[1] Chief Engineer of Tests, Ohio Highway Dept., Columbus, Ohio.

[2] From "Cooperative Tests of Slag by Seventeen Laboratories," January and February, 1928.

[3] "Comparison of Transverse and Compressive Test of Concrete," *Public Roads*, May, 1926, pp. 66 to 68.

Table I.—Results of Tests on Slag Showing Relation of Weight to Abrasion Loss.

Seventeen Laboratories Tests

Laboratory.	Weight per Cubic Foot, lb.	Variation, per cent	Standard Abrasion Test Loss, per cent	Variation, per cent	Modified Abrasion Test Loss, per cent	Variation, per cent	Weight per Cubic Foot, lb.	Variation, per cent	Standard Abrasion Test Loss, per cent	Variation, per cent	Modified Abrasion Test Loss, per cent	Variation, per cent	Weight per Cubic Foot, lb.	Variation, per cent	Standard Abrasion Test Loss, per cent	Variation, per cent	Modified Abrasion Test Loss, per cent	Variation, per cent	Weight per Cubic Foot, lb.	Variation, per cent	Standard Abrasion Test Loss, per cent	Variation, per cent	Modified Abrasion Test Loss, per cent	Variation, per cent
	Slag A						Slag B						Slag C						Slag D					
U. S. Bureau of Public Roads	78.0	2.5	15.8	16.2	19.6	0.5	74.0	0.1	15.3	15.9	22.8	0.0	83.0	1.3	13.4	3.8	14.1	34.7	102.0	1.5	6.6	40.4	15.7	9.8
Iowa State Highway Dept	77.3	1.6	15.4	13.2	19.8	1.5	73.0	1.2	12.8	3.0	24.0	5.3	81.3	0.7	13.3	3.1	22.2	2.7	99.2	1.2	5.5	17.0	13.2	7.7
Portland Cement Assn	74.8	1.7	14.1	3.7	21.0	7.7	72.8	1.5	12.9	2.2	24.3	6.6	80.3	1.9	14.6	13.2	23.6	9.2	99.5	0.9	6.2	32.0	14.0	2.1
New Hampshire Highway Dept	74.1	2.6	9.1	33.1	13.8	29.2	74.6	0.9	9.5	28.0	16.4	28.1	80.7	1.5	5.1	60.4	14.7	31.9	99.3	1.1	1.0	78.7	7.2	49.6
Standard Slag Co	79.0	3.8	12.2	10.3	22.2	13.8	76.0	2.8	11.6	12.1	25.5	11.8	83.0	1.3	10.5	18.6	27.3	26.4	103.0	2.5	5.2	10.7	17.8	24.5
Ohio State Highway Dept	79.3	4.2	12.2	10.3	17.2	11.8	76.6	3.6	7.8	40.8	21.0	7.9	85.4	4.3	12.4	3.8	18.6	14.0	102.7	2.3	3.8	19.1	11.9	16.8
Allegheny County, Pa	76.3	0.3	12.3	9.6	18.3	6.2	73.8	0.1	14.1	6.8	22.0	3.5	80.7	1.5	14.1	9.3	22.3	3.2	99.0	1.4	4.9	4.2	16.0	11.9
Minnesota Highway Dept	75.3	1.0	13.4	1.5	18.1	7.2	74.5	0.8	12.1	8.3	23.2	1.8	83.4	1.8	10.7	17.0	21.0	2.7	101.3	0.9	4.3	8.5	14.2	0.7
West Virginia Highway Dept	75.2	1.2	15.0	10.3	24.5	25.6	73.6	0.4	14.2	7.6	24.5	7.5	81.7	0.2	12.9	0.0	21.1	2.3	98.5	2.0	4.2	10.7	15.8	10.5
Pennsylvania State Highway Dept	78.2	2.8	13.0	4.4	21.7	11.3	77.0	4.2	12.1	8.3	22.1	3.1	84.1	2.7	12.1	6.2	22.3	3.2	104.7	4.3	4.5	4.2	13.2	7.7
Michigan Highway Dept	75.0	1.4	12.3	9.5	20.4	4.6	73.7	0.3	12.7	3.8	23.3	2.2	82.1	0.2	11.5	10.8	21.4	0.9	100.0	0.4	4.6	2.1	15.5	8.4
Virginia Highway Dept	76.0	0.1	11.0	19.1	18.2	6.6	74.5	0.8	12.0	9.1	20.2	11.4	83.5	1.9	14.4	11.6	21.2	1.8	99.5	0.9	5.6	19.1	13.7	4.2
University of Pennsylvania	73.4	3.6	10.8	20.6	23.2	18.9	74.4	0.7	14.5	9.8	24.8	8.7	76.4	6.7	13.6	5.4	27.3	26.4	102.7	2.3	4.5	4.2	17.7	23.8
Cornell University	75.6	0.6	23.0	69.1	15.4	21.0	71.3	3.5	21.5	62.8	18.9	17.1	82.3	0.5	18.3	41.8	18.8	12.9	98.6	1.8	5.7	21.3	13.5	5.6
France Slag Co	77.0	1.2	13.1	3.7	18.3	6.2	71.0	3.9	12.7	3.8	24.0	5.3	82.1	0.2	11.3	12.4	22.2	2.7	99.2	1.2	4.4	6.4	13.5	5.6
Louisiana University	75.0	1.4	15.7	15.4	19.6	0.5	74.2	0.4	14.5	9.8	25.3	10.9	82.5	0.7	14.8	14.7	23.0	6.5	99.5	0.9	3.7	21.3	13.9	2.8
Rochester Municipal	74.0	2.8	13.4	1.5	21.1	8.2	72.2	2.3	14.4	9.1	25.2	10.4	80.7	1.5	16.4	27.1	26.9	24.5	97.7	2.7	5.0	6.4	16.0	11.9
Average	76.1	1.9	13.6	14.8	19.5	10.6	73.9	1.6	13.2	14.2	22.8	8.3	81.9	1.7	12.9	15.2	21.6	12.1	100.4	1.7	4.7	18.0	14.3	12.0
Maximum	....	4.2	....	69.1	....	29.2	....	4.2	....	62.8	....	28.1	....	6.7	....	60.4	....	34.7	....	4.3	...	78.7	....	49.6
	Slag E (Same as Slag A)						Slag F (Same as Slag B)						Slag G (Same as Slag C)						Slag H (Same as Slag D)					
U. S. Bureau of Public Roads	78.0	1.7	12.4	6.0	21.1	8.8	75.0	0.1	15.1	19.8	24.2	12.0	85.0	2.9	13.2	15.8	23.9	10.1	100.0	0.9	6.0	50.0	16.5	12.2
Iowa State Highway Dept	74.5	2.9	14.0	19.6	17.2	11.3	73.2	2.5	12.3	2.4	20.4	5.5	80.2	2.9	12.7	11.4	19.7	9.2	98.0	2.8	4.8	20.0	14.1	4.1
Portland Cement Assn	74.4	3.0	14.5	23.9	20.3	4.6	74.7	0.5	14.1	11.9	22.7	5.1	81.5	1.3	13.7	20.2	22.0	1.4	99.7	1.2	4.8	20.0	15.0	2.0
New Hampshire Highway Dept	74.6	2.7	3.9	66.6	18.0	7.2	76.1	1.3	9.8	22.2	17.8	17.6	79.8	3.4	4.1	64.0	19.5	10.1	100.1	0.8	0.4	90.0	13.4	8.8
Standard Slag Co	79.0	3.0	10.7	8.5	23.2	19.5	75.0	0.1	12.7	0.8	26.3	21.7	83.0	0.5	13.7	20.2	26.5	22.1	103.0	2.1	4.5	12.5	17.6	19.7
Ohio State Highway Dept	80.0	4.3	12.4	6.0	17.4	10.3	76.2	1.5	10.2	19.0	19.6	9.2	86.0	4.1	12.2	7.0	18.2	16.1	103.2	2.3	3.8	5.0	12.3	16.3
Allegheny County, Pa	76.2	0.6	14.4	23.0	18.4	5.1	75.3	0.3	14.0	11.1	20.3	6.0	82.9	0.4	10.5	7.9	22.4	3.2	102.5	1.6	3.5	12.5	13.9	5.4
Average	76.7	2.6	11.7	21.9	19.4	9.5	75.1	0.9	12.6	12.4	21.6	11.0	82.6	2.2	11.4	20.9	21.7	10.3	100.9	1.7	4.0	30.0	14.7	9.8
Maximum	....	4.3	....	66.6	....	19.5	....	2.5	....	22.2	....	21.7	....	4.1	....	64.0	....	22.1	....	2.8	...	90.0	....	19.7

Wear tests were made on 2.5-in. cylinders cut from broken pieces of the beams, using for the purpose a calyx shot drill. The machine used for the wear test was the standard Dorry hardness apparatus, modified to give a wearing surface of 2.5 in.; this was accomplished by providing for the spreading of the quartz sand over the full face of the grinding disk. The test was further modified by increasing the total pressure on the grinding surface, a 5-lb. lead weight being attached to the top of the test specimen. The standard holder was of course eliminated. The total pressure, including the weight of the test cylinder, was adjusted to give a total weight of 3250 g.

TABLE II.—RESULTS OF TESTS ON SLAG CONCRETE.

Ohio State Highway Department Tests.

	Slag A	Slag B	Slag C	Slag D	Slag I	Average
Weight, compact, lb. per cu. ft.[a]	76.1	73.9	81.9	100.4	70.0	....
Standard abrasion, per cent[a]	13.6	13.2	12.9	4.7	16.2	....
Modified abrasion, per cent[a]	19.5	22.8	21.6	14.3	19.8	....
MIX OF 6.7 SACKS PER CU. YD.						
TESTED AT 28 DAYS:						
Compressive strength, lb. per sq. in.	5263	5300	5130	4630	4510	4967
Flexural strength (Clemmer machine), lb. per sq. in.	648	560	593	700	614	623
Flexural strength (Ohio machine), lb. per sq. in.	742	741	762	830	733	762
Wear loss, g	12.4	14.2	10.8	8.4	11.9	11.5
Absorption, per cent	6.1	6.6	5.5	5.2	7.0	6.1
TESTED AT 90 DAYS:						
Compressive strength, lb. per sq. in.	5200	5260	4860	4650	5230	5040
Flexural strength (Clemmer machine), lb. per sq. in.	767	672	772	702	635	710
Flexural strength (Ohio machine), lb. per sq. in.	915	753	912	843	880	861
MIX OF 6.4 SACKS PER CU. YD.						
TESTED AT 28 DAYS:						
Compressive strength, lb. per sq. in.	3783	4343	4250	3810	4073	4052
Flexural strength (Clemmer machine), lb. per sq. in.	570	593	624	633	615	607
Flexural strength (Ohio machine), lb. per sq. in.	742	675	799	743	763	744
Wear loss, g	12.0	12.5	11.9	8.9	14.7	12.0
Absorption, per cent	6.5	6.6	4.7	4.5	7.1	5.9
TESTED AT 90 DAYS:						
Compressive strength, lb. per sq. in.	4480	4630	4540	4420	4960	4606
Flexural strength (Clemmer machine), lb. per sq. in.	635	647	740	730	625	675
Flexural strength (Ohio machine), lb. per sq. in.	773	778	922	830	785	818

[a] Average of 17 laboratories except slag I, which was tested in only 2 laboratories.

Absorption tests of the concrete were made on broken pieces of beams, by immersing the test specimens in water for 48 hours and then drying in an oven at 220° F. to constant weight.

Tested at 28 and 90 days after moist storage at 70° F., the results were as shown in Table II.[1]

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[1] From "Report of Tests on Slag and Slag Concrete," by Ohio State Highway Department, July, 1928.

U. S. Bureau of Public Roads Tests:

The test results reported by Harsch offer further data on the relation of the abrasion loss of slag to its concrete-making properties. This series of tests, conducted under the auspices of the U. S. Bureau of Public Roads, was preceded by the Bureau's survey of 32 slag plants in all sections of the country where blast-furnace slag is produced. Samples from each of these plants were subjected to routine physical and chemical tests, including standard Deval abrasion and weight determination. The slags from 18 of the plants were then used as the coarse aggregate in concrete, which was tested in compression, and for wearing resistance in the Talbot-Jones machine. The cylinders were fabricated according to the Society's Standard Method of Making Compression Tests, six cylinders being made for each slag sample. The wear specimens were 8 by 8 by 5 in., numbering 5 for each plant. The mix throughout was 1:2:3 by volume, but the materials were measured by weight. Tests on the concrete after 28 days moist storage, and on slags from the 18 plants gave the data in Table III.[1]

TABLE III.—RESULTS OF SLAG AND CONCRETE TESTS.
U. S. Bureau of Public Roads Tests.

SLAG	WEIGHT PER CUBIC FOOT, COMPACT, LB.	LOSS IN STANDARD ABRASION TEST, PER CENT	COMPRESSIVE STRENGTH, OF CONCRETE, LB. PER SQ. IN.	TALBOT-JONES TEST ON CONCRETE, WEAR, PER CENT
No. 1	76.6	19.5	3359	11.2
No. 2	85.4	15.4	3316	10.1
No. 3	88.4	13.7	3510	9.2
No. 4	96.2	10.1	3219	8.6
No. 8	79.4	13.0	3353	10.1
No. 10	92.6	8.6	3159	10.3
No. 13	83.5	14.5	3422	7.0
No. 15	88.4	9.5	3547	9.5
No. 16	86.4	14.4	3565	9.8
No. 17	85.6	21.0	3265	8.3
No. 21	89.2	18.3	3069	9.2
No. 23	72.9	16.5	3051	10.8
No. 25	95.1	19.9	2936	8.7
No. 26	90.6	15.4	3064	8.9
No. 27	90.6	13.1	3231	9.2
No. 28	87.8	19.5	3656	9.3
No. 29	86.8	14.7	3409	9.3
No. 30	87.7	11.0	2906	11.1

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[1] From *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 255 (1923).

NEW INVESTIGATIONS

Five testing laboratories agreed to carry out a series of tests in connection with the problem of relation of abrasion loss to concrete-making properties as follows:

National Crushed Stone Association (A. T. Goldbeck)
France Stone Co. (H. F. Kriege)
National Slag Association (Fred Hubbard)
U. S. Bureau of Public Roads (F. H. Jackson)
Ohio Highway Department (The late Mr. A. S. Rea)

To each of the laboratories eighteen samples of slag were sent from six slag companies, representing the complete range in weight of commercial slags produced by each company. Two additional slags (extremely light weight, hand-picked materials) were selected and shipped to each laboratory in order to obtain results on slags below the Society's requirements for weight.[1] This procedure insured materials having a wide range in weight and abrasion loss.

Slag No. 7 is an extremely light weight, hand-picked material which was introduced into this series of tests to show the effect of light weight, low specific gravity, friable particles. Slag No. 13 is a decidedly non-uniform material ranging from very light weight to dense particles Slag No. 15, while comparatively light in weight, is composed of extremely uniform individual pieces of apparently very good strength in themselves. Slag No. 19 is composed of rather light weight particles some of which are somewhat friable. All other materials are what would be considered normal commercial slags as ordinarily produced.

The twenty slags were graded as follows for use in the concrete and in making weight and void determinations:

Passing ⅜-in., retained on No. 4 square mesh sieves.....	10 per cent
Passing ¾-in., retained on ⅜-in. square mesh sieves......	21 per cent
Passing 1-in., retained on ¾-in. square mesh sieves......	14 per cent
Passing 1½-in., retained on 1-in. square mesh sieves.....	28 per cent
Passing 2-in., retained on 1½-in. square mesh sieves.....	27 per cent

The tests on the twenty slags in each laboratory included (1) standard abrasion test according to the Society's Standard Method of Test for Abrasion of Rock (D 2 – 26)[2] except that a volume of 4000 cu. cm. of material was used instead of 5000 g., (2) modified abrasion test according to the Society's Tentative Method of Test for Abrasion of Gravel (D 289 – 28 T),[1] "A" grading, (3) weight determination according to the Society's Standard Method of Test for Unit Weight of Aggregate for Concrete (C 29 – 27),[2] and also on the material in a loose condition, (4) specific gravity and absorption determinations using either the Society's Standard Method of Test for Apparent Specific Gravity of Coarse Aggregates (D 30 – 18)[3] or the methods prescribed by the U. S. Department of Agriculture, *Bulletin No. 1216*, or that of the American Association of State Highway Officials, also specific gravity and absorption determinations on a large size sample of aggregate, approximately $\frac{1}{2}$ cu. ft., graded $\frac{3}{4}$ to 2 in., (5) chemical analyses made by the National Slag Association Laboratory only, (6) sodium sulfate soundness tests (20 cycles) made by the National Slag Association Laboratory only.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 822 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 207.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 463.

TABLE IV.—RESULTS OF TESTS ON SAND USED BY FIVE COOPERATING LABORATORIES.

	LABORATORY A	LABORATORY B	LABORATORY C	LABORATORY D	LABORATORY E
Total Retained on No. 4 Sieve	..	6.7	....	1	1.2
Total Retained on No. 8 Sieve	..	25.4	....	8	10.1
Total Retained on No. 10 Sieve	11	....	10.8	..	....
Tolal Retained on No. 14 Sieve	..	47.8	....	..	25.6
Total Retained on No. 16 Sieve	..	....	....	18	....
Total Retained on No. 20 Sieve	28	....	32.8	..	....
Total Retained on No. 28 Sieve	..	68.7	....	..	45.9
Total Retained on No. 30 Sieve	41	....	45.8	38	....
Total Retained on No. 40 Sieve	68	....	58.2	..	....
Total Retained on No. 48 Sieve	..	93.9	....	..	91.2
Total Retained on No. 50 Sieve	86	....	77.4	78	....
Total Retained on No. 60 Sieve	..	....	86.2	..	....
Total Retained on No. 80 Sieve	95	....	93.0	..	....
Total Retained on No. 100 Sieve	96	99.0	97.0	97	99.2
Total Retained on No. 200 Sieve	97	....	....	99	....
Fineness Modulus	..	3.42	....	..	2.73
Clay and Silt, per cent	2.9	0.8	1.8	..	0.4
Colorimetric Test	Satisfactory	No. 1	No. 1	..	No. 1

In the concrete tests the following conditions governed:

Cement.—Any available cement conforming to the Society's Standard Specifications and Tests for Portland Cement (C 9 – 26).[4]

Sand.—Any available sand conforming to the Society's Tentative Specifications for Concrete Aggregates (C 33 – 28 T).[5] Tests for sieve analysis were according to the Society's Standard Method of Test for Sieve Analysis of Aggregates for Concrete (C 41 - 24),[1] decantation tests according to the Society's Standard Method of Decantation Test for Sand and Other Fine Aggregates (D 136 - 28),[2] and tests for organic impurities in accordance with the Society's Standard Method of Test for Organic Impurities in Sands for Concrete (C 40 - 27).[3] The sands used by the various laboratories were tested with the results shown in Table IV.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 940 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 471.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 120.

[3] *Ibid*, p. 466.

[4] *Ibid.*, p. 23.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 822 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 207.

Mix.—1:2:3 by dry rodded volumes.

Consistency.—1½ to 2½ in. slump.

Water-Cement Ratio.—Consistency kept the same and the net water-cement ratio reported after deducting for the absorption of the aggregates after 30 minutes' immersion.

Mixing Method.—Either trowel, shovel, or mechanical mixer was permissible. The methods used were as follows:

Laboratory A.—The concrete for the compression specimens was mixed and the specimens were fabricated in accordance with the Society's Standard Methods of Making Compression Tests of Concrete (C 39 - 27)[4]. The concrete for the flexure specimens was mixed by shovels in a large, shallow galvanized-iron pan.

Laboratory B.—The constituents of each batch were mixed for two minutes in a two-bag mixer. The wet batch was then dumped on a mixing board and the slump and cylinders were made according to the Society's Standard Methods C 39. The beams were made half by filling the forms, rodding the layer 50 times, filling the forms, rodding another 50 times, troweling once along the sides, striking off the excess concrete and troweling the surface just enough to acquire some degree of smoothness.

Laboratory C.—Concrete for both beams and cylinders was made by the hand-mixing method. The sand and cement were mixed dry until a homogeneous mixture was obtained. The coarse aggregate was then added and mixed dry. Water was then added until the desired consistency was obtained, after which the concrete was turned and spaded alternately three times and the test specimens were cast.

Laboratory D.—The concrete was mixed by hand for beams and cylinders. A batch of about one and one-half cubic feet of concrete, enough for one beam and three cylinders, was mixed in a large, shallow galvanized pan by two men using shovels. First, the sand and cement were mixed until the color was uniform, then water was slowly added and the concrete thoroughly mixed until the desired consistency was obtained, thus requiring several minutes for mixing each batch.

Laboratory E.—Mixing of all concrete was done in a laboratory mixer. The sand and cement were mixed dry for two minutes. Coarse aggregate was then added and mixed dry for two minutes, after which the water was added and the whole batch was mixed for five minutes. The cylinders for compression tests were molded according to the Society's Standard Methods C 39. Concrete in the beams was placed in two equal layers, each layer being rodded and the sides afterward spaded with a blunt mason's trowel. The top was then struck off and floated.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 124.

[2] 1928 Supplement to Book of A.S.T.M. Standards, p. 161.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 123.

[4] *Ibid.*, p. 112.

Compression Tests.—Six concrete cylinders, 6 by 12 in., were made from each slag sample, three tested at 28 days and three at 90 days.

Flexure Tests.—6 by 6-in. concrete beams were made from each slag sample for testing at 28 and 90 days of age. Various testing methods were used as follows:

Laboratory A.—The flexure tests were made on 6 by 6 by 30-in. beams tested as cantilevers, two breaks being obtained on each beam.

Laboratory B.—The flexure tests were made on 6 by 6 by 44-in. beams tested as cantilevers on a machine of the same design as that used by the Ohio State Department of Highways. In this machine the load acts through a bearing plate on top at the end of the beam and a knife edge bearing on the bottom 10 in. from the top bearing plate. The load is applied by a worm and gear arrangement through a steel extension arm with the load recorded by a dynamometer.

Laboratory C.—The flexure tests were made on 6 by 6 by 40-in. concrete beams using the same testing method as laboratory B.

Laboratory D.—The flexure tests were made on 6 by 6 by 36-in. concrete beams. They were tested as simple beams with center loading using a span of 20 in. The load was so applied that the extreme fibers were stressed at approximately 190 lb. per sq. in. per minute. The bearing blocks were of a special design which insured that the forces applied to the beams were vertical only and applied without eccentricity.

Laboratory E.—The flexure tests were made on 6 by 6 by 40-in. concrete beams using the same testing method as laboratory B.

Absorption Tests of Concrete.—The absorption tests were made on broken pieces of beams as follows:

Laboratories A, C and E.—Broken pieces of beams were immersed in water for 48 hours after which they were dried to constant weight. The percentage of absorption was calculated from the loss in weight on drying.

Laboratory B.—Broken pieces of beams were dried to constant weight after which they were immersed in water for a period of 48 hours. The percentage of absorption was calculated from the loss in weight on drying.

Laboratory D.—The absorption test on concrete was made by first drying the specimens in an oven to constant weight, allowing them to cool and then immersing in water at room temperature and making weight determinations until there was no further material gain in weight.

Wear Tests on Concrete.—Wear tests were made by laboratories B, C and E as follows:

Laboratory B.—The wear test specimens consisted of blocks shaped as arc segments to fit the rotating surface of the Dorry hardness machine. Each block weighed approximately 3500 g. The dimensions of each block were: outer length, 9.43 in., inner length, 5.73 in., width, 4.51 in., thickness, 3.0 in. This gave a bearing surface area of 35 sq. in. Standard Ottawa sand (No. 30 to No. 40) was fed from a special hopper which distributed the sand across the whole bearing surface of the block. An additional load of approximately 30 lb. (13,700 g.) was placed on the test block to increase the rate of wear.

As a preliminary to a run, each block was dried and given 500 revolutions of the machine on the top and on the bottom so that coarse aggregate was exposed. The block was then weighed. It was then given 500 more revolutions on both the top and the bottom surfaces and reweighed. The loss in weight occurring during the 1000 revolutions was calculated and reported in per cent.

Laboratory C.—The wear testing apparatus consists of an arrangement of emery wheel dresser cutters mounted on a horizontal axis supported at three points. The over-all length of the cutting apparatus is approximately 4½ in. with ⅜-in. separation at the central bearing point. Each individual set of cutters consists of two cutters and one washer, making a total of 36 cutters and 9 washers, the diameter of the cutters being 1⅜ in. This apparatus is mounted on the drill press in exactly the same manner as in the diamond core drill which is in general use in laboratories equipped for testing stone. The cutter is turned at the rate of 430 r.p.m., and the machine is calibrated to give 100-lb. pressure between the apparatus and the test specimen. The practice followed was to cut a 4½-in. section ¼ in. in depth from the top, side and bottom of the two pieces of the beam used for the flexure test, at the age of 49 days. In order to standardize the cutting apparatus alternating pairs of cutters were changed at the beginning of the test on each beam. The results given are an average of six tests taken on each beam and are reported in inches depth of wear produced in a 10 minute run of the machine.

TABLE V.—CHEMICAL ANALYSIS OF SLAG USED IN TESTS.

Slag	Silica, SiO_2, per cent	Aluminum Oxide, Al_2O_3, per cent	Iron Oxide, FeO, per cent	Manganese Oxide, MnO, per cent	Calcium Oxide, CaO, per cent	Magnesium Oxide, MgO, per cent	Sulfur, per cent
No. 1	37.06	12.82	0.56	0.26	42.17	6.68	0.57
No. 2	35.63	14.88	0.75	0.77	44.28	3.72	0.68
No. 3	34.79	17.54	0.63	0.39	43.26	3.13	0.55
No. 4	37.38	10.81	1.01	0.31	42.38	5.86	1.09
No. 5	36.88	13.07	0.69	0.27	44.32	3.52	0.83
No. 6	36.99	10.40	0.75	0.25	44.50	5.45	1.05
No. 7	33.52	14.29	0.75	0.49	36.58	9.98	1.48
No. 8	36.01	13.87	0.88	0.44	42.23	5.71	1.48
No. 9	40.67	10.30	0.83	0.26	26.51	19.86	0.75
No. 10	39.63	13.86	0.63	0.26	37.50	7.94	0.83
No. 11	39.79	13.96	0.63	0.36	37.18	7.86	0.97
No. 12	40.59	13.11	0.50	0.37	37.18	7.95	0.92
No. 13	33.43	15.38	2.42	0.37	43.56	1.84	1.30
No. 14	38.11	12.33	0.72	0.26	42.09	6.15	0.88
No. 15	32.58	12.50	0.76	0.28	41.39	10.30	1.74
No. 16	38.49	12.40	0.75	0.20	37.85	9.00	1.05
No. 17	34.68	14.02	0.90	0.72	40.99	7.04	1.55
No. 18	43.02	8.60	0.70	0.12	40.88	6.37	1.19
No. 19	31.61	10.00	0.85	0.48	36.56	14.63	1.25
No. 20	33.35	12.78	0.71	1.32	39.28	10.37	1.69
Average	36.71	12.85	0.82	0.41	40.03	7.67	1.09

Laboratory E.—The concrete testing apparatus was the same as that used by the Columbus Testing Laboratory for testing concrete floor surfaces. It consists of a mechanically driven arm on the end of which is fastened a guide in which is placed a steel weight which is used as the wearing device. Standard Ottawa sand was used as an abrasive material under the weight, which was moved back and forth over the concrete with combined rocking and sliding motion. Tests were made on top of sections of the concrete beams at 28 days and 90 days of age. Wear results are recorded as depth of wear in inches after a 7-hour run of the machine.

The wear results obtained by this apparatus are not considered entirely satisfactory, as a few grains of large sand particles near the surface materially affect the test. The results of this method of test are more representative of the wear on the mortar than on the coarse aggregate.

TABLE VI.—RESULTS OF SOUNDNESS TESTS ON SLAG.

SLAG	
No. 1	20 cycles. One piece showed numerous small cracks at 11 cycles.
No. 2	20 cycles. One piece in five at 8 cycles; broken up into small pieces at 20 cycles.
No. 3	20 cycles. One piece in three at 14 cycles.
No. 4	O.K. at 20 cycles.
No. 5	O.K. at 20 cycles.
No. 6	O.K. at 20 cycles.
No. 7	20 cycles. One piece in three at 12 cycles, in six at 18; one piece in four at 12 cycles, in six at 18.
No. 8	O.K. at 20 cycles.
No. 9	O.K. at 20 cycles.
No. 10	O.K. at 20 cycles.
No. 11	O.K. at 20 cycles.
No. 12	20 cycles. One chip, $\frac{3}{4}$ in. in size, at 17 cycles.
No. 13	O.K. at 20 cycles.
No. 14	O.K. at 20 cycles.
No. 15	One piece in two at 14 cycles.
No. 16	O.K. at 20 cycles.
No. 17	O.K. at 20 cycles.
No. 18	O.K. at 20 cycles.
No. 19	O.K. at 20 cycles.
No. 20	O.K. at 20 cycles.

The results of the tests on the aggregates and the concrete are given in Tables V to XVI.

SUMMARY AND CONCLUSIONS

In studying the test results special attention is given to the requirements of 70-lb. per cu. ft. compact weight, not more than 15 per cent standard abrasion loss and not more than 24 per cent modified abrasion loss (grading "A") included in specifications.

Study of Ohio State Highway Department Test Results:

In considering the data of Mr. Rea's tests, presented earlier in this report, the abrasion and weight values plotted in Figs. 1 to 4 are the averages of those obtained by the seventeen cooperating laboratories with the exception of slag I, which was not included in the cooperative tests. The values on slag I are as determined by the Ohio State Highway Laboratory and the Standard Slag Co. The relative compressive strengths are the averages of 28 and 90-day results on the two mixes used. The relative flexural strengths are the average of 28 and 90-day results of the two mixes and of the two testing machines used for breaking the beams. The relative wear and absorption results are the average of tests at 28 days on the two mixes. (See Table II).

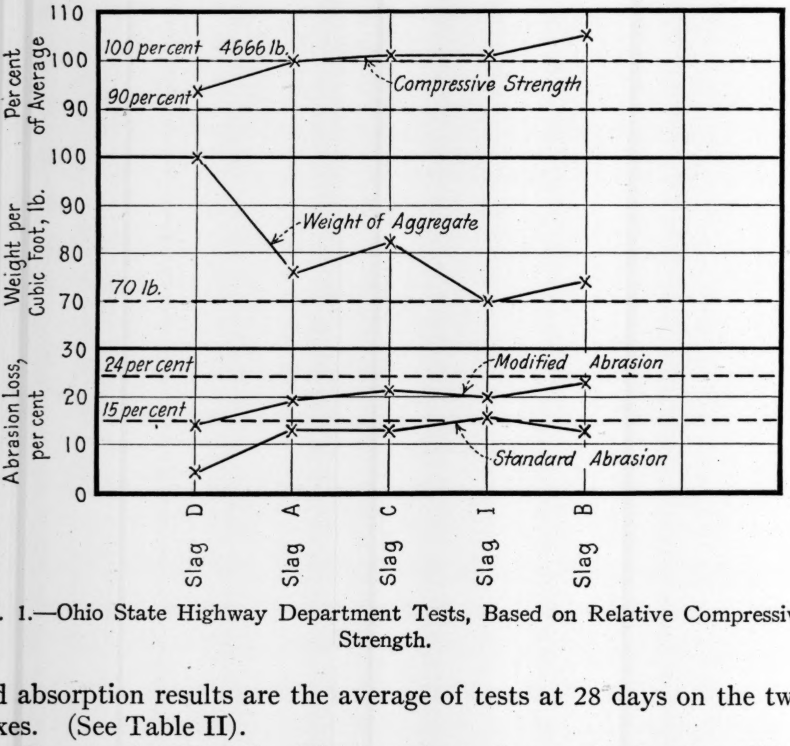

FIG. 1.—Ohio State Highway Department Tests, Based on Relative Compressive Strength.

Compressive Strength.—Figure 1 shows the standard and modified abrasion losses, the compact weight per cubic foot of the aggregate and the relative compressive strengths of the concrete, plotted in the order of the ascending values of compressive strength. None of the materials in this series of tests is less than 70 lb. per cu. ft. compact weight and none shows more than 24 per cent modified abrasion loss. Slag I is the only one which shows more than 15 per cent standard abrasion loss.

A study of this figure shows that an increase in compressive strengths was accompanied by a somewhat similar increase in abrasion losses and a decrease in weights per cubic foot. Thus the slag showing the lowest abrasion loss and highest weight gave the poorest strength, although all strengths were perfectly satisfactory studied from either the standpoint of actual strength or relative strength when compared one with another. The one slag which would be eliminated by a 15-per-cent abrasion loss limitation showed next to the highest strength of all materials considered. From this study it is concluded:

1. That high abrasion loss in slag is not an indication of inferior concrete-making qualities as shown by compression tests, but rather the reverse.

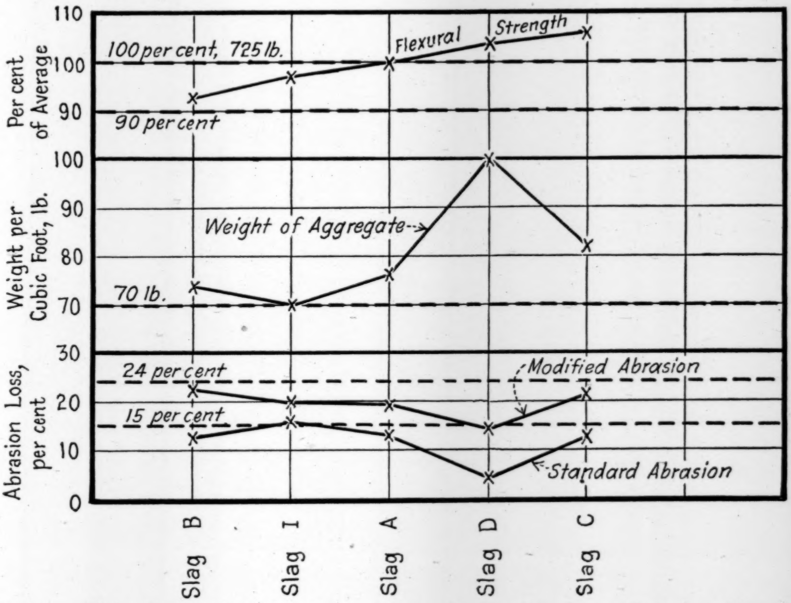

FIG. 2.—Ohio State Highway Department Tests, Based on Relative Flexural Strength.

2. That the slags of medium weight (70 to 85 lb. per cu. ft.) gave better compressive strengths than the extremely heavy slag D with a weight of 100.4 lb. per cu. ft.

3. That all materials used gave entirely satisfactory compressive strengths.

Flexural Strength.—Figure 2 shows the standard and modified abrasion test results, compact weight per cubic foot and the quality of the concrete as measured by flexure tests, plotted in the order of increasing relative flexural strengths. As in the case of the compression tests, all materials give entirely satisfactory results. There is a tendency for the heavier materials to produce higher flexural strengths. The one slag showing more than 15 per cent standard abrasion loss gives next to the lowest strength, but this strength is only 3 per cent below the average. The extremely heavy and low-abrasion slag D gives next to the highest flexural strength results.

The results from this series show:

1. That all materials used (ranging from 70 to 100 lb. per cu. ft.) gave entirely satisfactory flexural strengths.

2. That, generally, the heavier slags gave higher flexural strengths than the lighter slags.

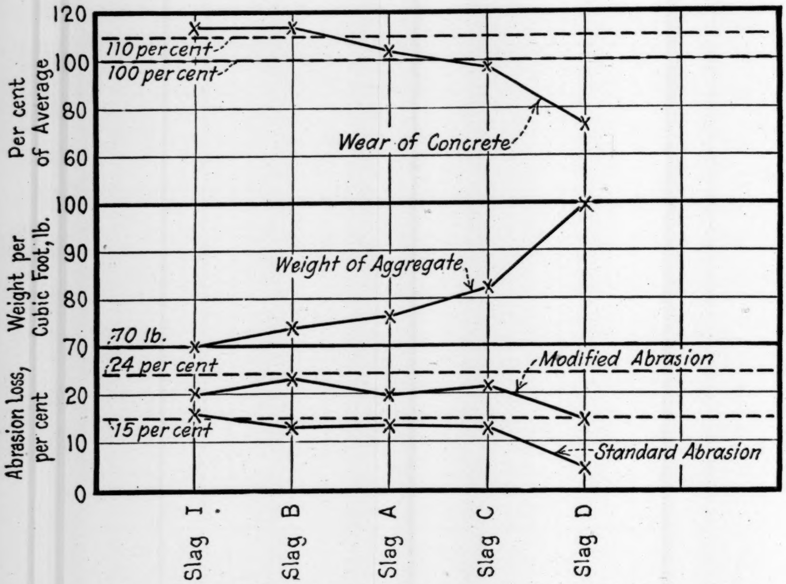

FIG. 3.—Ohio State Highway Department Tests, Based on Relative Wear Resistance.

Wear of Concrete.—Figure 3 shows the test results plotted according to the decreasing relative wear of the concrete. This chart indicates very clearly that the wear of the concrete is definitely affected by the weight per cubic foot of the aggregate, the concrete containing the heavier slags showing less wear. The low abrasion slags also show low wear, but the relationship is less definite.

Two aggregates, I and B, show more than 10 per cent above the average wear. These are the two lightest materials and one of them, slag I, shows more than 15 per cent standard abrasion loss. The conclusions drawn from this series of tests are therefore:

1. That when subjected to this particular wear test the concrete containing the heavier slags shows less wear than the lighter weight materials.

2. That there is nothing indicated by the abrasion tests that is not more conclusively shown by the weight per cubic foot determination.

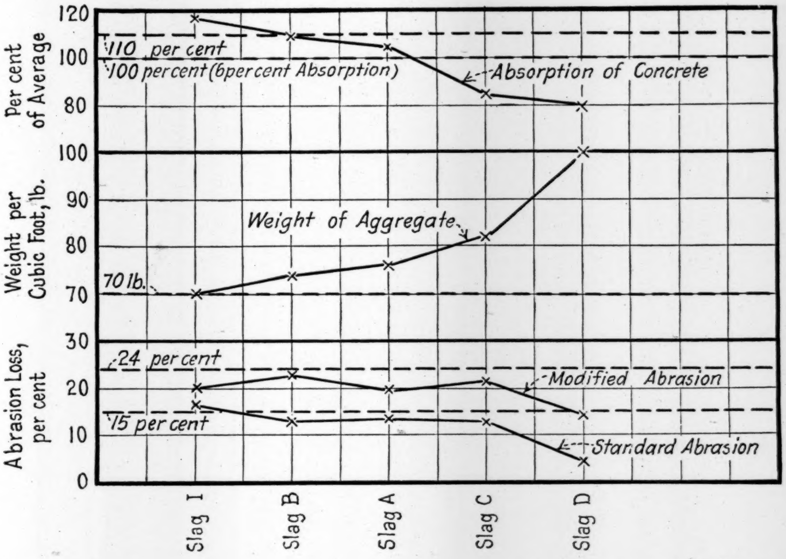

FIG. 4.—Ohio State Highway Department Tests, Based on Relative Absorption of Concrete.

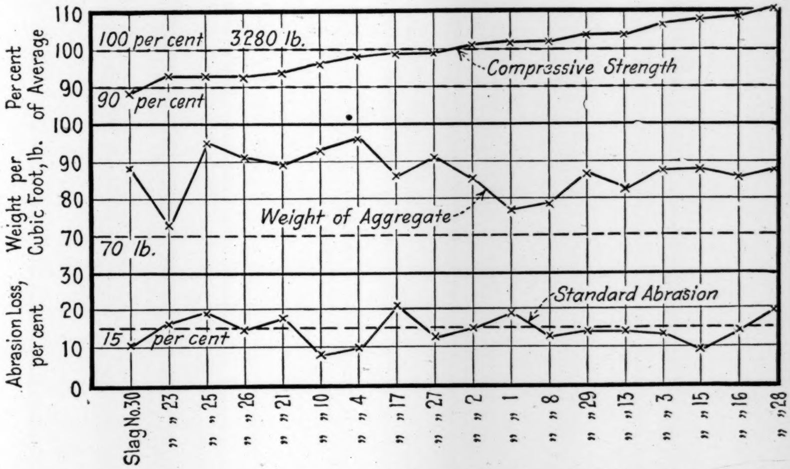

FIG. 5.—U. S. Bureau of Public Roads Tests, Based on Relative Compressive Strength.

3. That there is a general relation between weight per cubic foot of the aggregate and its abrasion losses, the higher weights being accompanied by lower abrasion.

TABLE VII.—RESULTS OF TESTS FOR WEIGHT PER CUBIC FOOT OF SLAG.

Slag	Laboratory A			Laboratory B			Laboratory C			Laboratory D			Laboratory E			Average, All Laboratories		Mean Deviation from Average, All Laboratories, per cent	Maximum Deviation, from Average, All Laboratories, per cent
	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Weight per Cubic Foot, lb.	Per Cent of Average, All Slags		
COMPACT WEIGHT																			
No. 1	77.0	95	2	78.2	97	1	79.0	93	0	78.6	95	0	80.5	97	2	78.7	95	1	2
No. 2	82.0	101	0	81.7	101	1	81.0	96	2	83.2	101	1	82.9	99	1	82.2	100	1	2
No. 3	87.0	107	4	90.1	111	0	94.0	111	4	90.8	110	0	90.1	108	0	90.4	109	2	4
No. 4	80.0	98	3	78.5	97	4	84.0	99	2	82.6	100	1	84.4	101	3	81.9	99	3	4
No. 5	82.0	101	2	82.0	101	2	84.0	99	1	82.2	100	1	84.2	101	1	82.9	100	1	2
No. 6	82.0	101	0	80.5	100	2	84.0	99	2	81.6	99	1	82.6	99	1	82.1	100	1	2
No. 7	64.0	79	1	63.0	78	1	64.0	76	1	63.2	77	1	62.8	75	1	63.4	77	1	1
No. 8	83.0	102	6	87.7	108	0	93.0	110	6	85.2	103	3	90.5	109	3	87.9	106	4	6
No. 9	92.0	113	1	90.2	111	3	95.0	112	2	92.5	112	1	96.2	115	3	93.2	113	2	3
No. 10	75.0	92	3	74.5	92	4	81.0	96	5	77.1	94	1	80.0	96	3	77.5	94	3	5
No. 11	92.0	113	1	89.2	110	4	94.0	111	1	92.8	113	0	95.6	115	3	92.7	112	2	4
No. 12	96.0	118	4	98.5	122	1	104.0	123	4	98.3	119	1	101	121	2	99.6	121	2	4
No. 13	74.0	91	2	70.0	87	3	74.0	87	2	73.5	89	2	69.7	84	4	72.2	88	3	4
No. 14	96.0	118	3	101.0	125	2	102.0	120	3	96.9	118	2	98.4	118	1	98.9	120	2	3
No. 15	66.0	81	3	66.2	82	3	74.0	87	9	66.0	80	3	66.8	80	2	67.8	82	4	9
No. 16	81.0	100	2	77.8	96	2	80.0	94	1	79.3	96	0	79.2	95	0	79.5	96	1	2
No. 17	79.0	97	1	78.1	97	2	82.0	97	3	80.6	98	1	79.2	95	1	79.8	97	2	3
No. 18	99.0	122	1	93.2	115	5	97.0	115	1	100.7	122	3	100.7	121	3	98.1	119	3	5
No. 19	68.0	84	2	66.0	82	5	76.0	90	10	68.4	83	1	67.3	81	3	69.1	84	4	10
No. 20	74.0	91	1	72.0	89	2	71.0	84	3	73.9	90	1	75.0	90	2	73.2	91	2	3
Average	81.4	100	2.1	80.9	100	2.4	84.7	100	3.1	82.4	100	1.2	83.4	100	2.0	82.6	100	2.2	3.9
LOOSE WEIGHT																			
No. 1	72.0	96	1	68.7	95	4	....	..	..	73.1	96	3	71.5	98	0	71.3	96	2	4
No. 2	75.0	100	1	74.0	102	0	..	..	..	75.0	99	1	72.4	99	2	74.1	100	1	2
No. 3	81.0	108	0	78.9	109	2	..	..	..	84.0	111	4	78.9	108	2	80.7	109	2	4
No. 4	75.0	100	2	69.5	96	5	..	..	..	75.9	100	3	73.4	101	0	73.5	99	2	5
No. 5	75.0	100	0	74.0	102	1	..	..	..	75.8	100	2	73.7	101	1	74 6	101	1	2
No. 6	74.0	99	1	70.5	97	4	..	..	..	76.4	101	5	71.4	98	2	73.1	99	3	5
No. 7	60.0	80	6	56.2	78	1	..	..	..	57.8	76	2	52.8	73	7	56.7	77	4	7
No. 8	77.0	103	2	81.7	113	4	..	..	..	78.2	103	1	78.5	108	0	78.9	107	2	4
No. 9	85.0	113	1	82.2	114	2	..	..	..	84.6	112	1	83.2	114	1	83.8	113	1	2
No. 10	69.0	92	1	64.0	90	6	..	..	..	70.8	93	4	69.4	95	2	68.3	92	3	6
No. 11	85.0	113	2	77.0	106	8	..	..	..	86.4	114	4	85.6	118	3	83.5	113	4	8
No. 12	90.0	120	0	90.2	125	1	..	..	..	90.0	119	0	88.5	122	1	89.7	121	1	1
No. 13	68.0	91	5	63.7	88	1	..	..	..	66.9	88	4	59.6	82	8	64.6	87	4	8
No. 14	90.0	120	1	88.8	123	0	..	..	..	89.8	118	1	88.2	121	1	89.2	121	1	1
No. 15	60.0	80	1	59.7	82	1	..	..	..	59.7	79	1	57.3	79	3	59.2	80	1	3
No. 16	74.0	99	3	70.4	97	2	..	..	..	73.8	97	3	69.8	96	3	72.0	97	3	3
No. 17	73.0	97	2	70.1	97	2	..	..	..	73.2	97	2	69.5	95	3	71.5	97	2	3
No. 18	92.0	123	3	85.0	117	5	..	..	..	92.6	122	3	88.7	122	1	89.6	121	3	5
No. 19	61.0	81	2	57.3	79	4	..	..	..	63.2	83	6	57.6	79	4	59.8	81	4	6
No. 20	67.0	89	0	66.0	91	1	..	..	..	68.5	90	3	65.5	90	2	66.8	90	1	3
Average	75.1	100	1.7	72.4	100	2.5	..	..	..	75.8	100	2.7	72.8	100	2.3	74.0	100	2.3	4.1

TABLE VIII.—RESULTS OF ABRASION TESTS ON SLAGS.

Slag	Laboratory A			Laboratory B			Laboratory C			Laboratory D			Laboratory E			Average All Laboratories		Mean Deviation from Average, All Laboratories, per cent	Maximum Deviation from Average, All Laboratories, per cent
	Abrasion Loss, per cent	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Abrasion Loss, per cent	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Abrasion Loss, per cent	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Abrasion Loss, per cent	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Abrasion Loss, per cent	Per Cent of Average, All Slags	Deviation from Average, All Laboratories, per cent	Abrasion Loss, per cent All Slags	Per Cent of Average, All Slags		
STANDARD ABRASION TEST[a]																			
No. 1	11.1	74	10	11.7	102	6	9.6	100	23	14.8	109	19	15.0	119	21	12.4	99	16	23
No. 2	12.2	81	27	5.7	50	40	8.2	85	15	13.0	96	35	8.9	71	7	9.6	77	25	40
No. 3	14.9	99	52	9.1	79	7	5.0	52	49	11.2	82	14	8.9	71	9	9.8	78	26	52
No. 4	8.9	59	5	10.1	88	8	6.7	70	29	11.1	82	18	10.3	82	10	9.4	75	14	29
No. 5	8.9	59	30	5.2	45	25	3.8	40	45	8.6	63	25	8.2	65	19	6.9	55	29	45
No. 6	11.7	77	52	4.0	35	48	5.2	54	33	9.9	73	28	7.5	60	3	7.7	62	33	52
No. 7	24.3	161	3	26.0	226	3	23.1	241	8	25.0	184	0	27.2	216	8	25.1	201	4	8
No. 8	12.9	85	23	10.1	88	4	9.5	100	10	11.4	84	8	8.9	71	15	10.5	84	12	23
No. 9	8.8	58	13	10.8	94	38	5.0	52	36	8.4	62	8	6.1	48	22	7.8	62	23	38
No. 10	25.2	167	30	17.0	148	12	16.5	172	15	19.6	144	1	18.6	148	4	19.4	155	12	30
No. 11	19.8	131	72	8.9	77	23	5.6	58	51	12.7	93	10	10.5	83	9	11.5	92	33	72
No. 12	7.3	48	11	6.1	53	8	5.0	52	24	8.1	60	23	6.3	50	5	6.6	53	14	24
No. 13	21.4	142	40	13.2	115	14	10.4	108	32	15.0	110	2	16.5	131	8	15.3	122	19	40
No. 14	6.9	46	3	5.3	46	25	5.8	60	18	8.5	63	20	9.3	74	31	7.2	57	19	31
No. 15	22.1	146	25	17.7	154	0	14.8	154	16	18.4	135	4	15.6	124	12	17.7	142	11	25
No. 16	17.8	118	7	16.2	141	2	15.1	157	9	18.2	134	22	15.5	123	7	16.6	133	9	22
No. 17	15.0	100	10	13.5	117	2	11.7	122	15	13.7	101	0	14.4	114	5	13.7	110	6	15
No. 18	6.7	44	46	3.5	30	24	3.2	33	30	5.0	37	9	4.8	38	4	4.6	37	23	46
No. 19	26.7	177	26	19.8	172	7	14.9	155	30	21.6	159	2	23.1	183	9	21.2	170	15	30
No. 20	18.5	123	13	16.7	145	2	12.2	127	25	17.0	125	4	17.3	137	6	16.3	130	10	25
Average	15.1	100	24.9	11.5	100	14.9	9.6	100	25.6	13.6	100	12.6	12.6	100	10.7	12.5	100	17.6	33.5
MODIFIED A.S.T.M. ABRASION—GRADING "A"																			
No. 1	41.0	177	40	26.3	127	10	22.6	120	23	26.6	123	9	30.0	134	2	29.3	136	17	40
No. 2	18.4	79	2	17.5	85	3	17.4	92	3	18.8	87	4	17.7	79	2	18.0	84	3	4
No. 3	16.0	69	5	15.0	72	2	13.2	70	14	15.5	72	1	16.9	75	10	15.3	72	6	14
No. 4	17.6	76	0	17.5	85	1	15.4	81	13	17.0	79	5	20.9	93	18	17.7	83	7	18
No. 5	17.8	77	1	18.1	87	1	16.4	87	9	17.2	80	5	20.6	92	14	18.0	85	6	14
No. 6	16.8	72	2	16.6	80	4	15.2	80	12	16.2	75	6	21.0	94	22	17.2	80	9	22
No. 7	36.2	156	26	24.8	120	14	25.2	133	13	31.0	144	8	26.6	119	8	28.8	134	14	26
No. 8	20.4	88	10	18.5	89	0	14.2	75	23	19.3	89	4	20.1	90	9	18.5	86	9	23
No. 9	16.2	70	9	13.8	67	7	12.0	63	20	14.6	68	2	17.7	79	19	14.9	69	11	20
No. 10	31.8	137	7	30.3	146	2	28.4	150	4	31.2	144	5	26.3	117	11	29.6	139	6	11
No. 11	22.2	96	0	25.0	121	13	23.4	124	5	21.2	98	5	19.3	86	13	22.2	105	7	13
No. 12	19.8	85	3	23.4	113	15	19.0	100	7	19.8	92	3	19.8	88	3	20.4	95	6	15
No. 13	20.8	90	4	17.7	86	12	18.6	98	7	20.5	95	2	22.4	100	12	20.0	94	7	12
No. 14	15.0	65	4	15.2	73	3	11.4	60	27	15.7	73	1	20.6	92	32	15.6	73	13	32
No. 15	24.4	105	6	17.3	84	25	18.8	99	19	23.3	108	1	31.5	141	36	23.1	107	17	36
No. 16	29.5	127	1	32.1	155	10	30.6	162	5	30.0	139	3	23.7	106	19	29.2	138	8	19
No. 17	25.6	110	2	25.0	121	0	23.6	125	6	25.0	116	0	26.3	117	5	25.1	118	3	6
No. 18	14.4	62	11	18.9	91	17	15.4	81	4	14.9	69	8	16.7	75	4	16.1	76	9	17
No. 19	32.0	138	18	21.2	102	20	24.0	127	11	29.4	136	9	28.6	128	6	27.0	126	13	20
No. 20	29.0	125	32	20.5	99	7	15.0	79	32	24.0	111	10	21.2	95	3	21.9	102	17	32
Average	23.2	100	9.1	20.7	100	8.3	18.9	100	12.3	21.6	100	4.5	22.4	100	12.4	21.4	100	9.4	19.7

[a] Standard test using 4000 cu. cm. of material instead of 5000 g.

Absorption of Concrete.—Figure 4 shows the quality of the concrete plotted according to its descending percentage of absorption. The results here shown are identical with those shown by Fig. 3 on wear. The materials appear in the same order and the same conclusions can logically be drawn.

Study of the U. S. Bureau of Public Roads Tests:

Compressive Strength.—Figure 5 shows the abrasion loss, weight and compressive strength results of the series of tests conducted by Harsch at the U. S. Bureau of Public Roads plotted according to the ascending values of the concrete as shown by compressive strength. A study of this series of tests shows that all slags were comparatively heavy, none weighing less than 70 lb. per cu. ft. There was only one (No. 30) which showed less than 90 per cent relative strength. This material had a weight of 87.7 lb. per cu. ft. and a standard abrasion loss of 11 per cent.

TABLE IX.—RESULTS OF SPECIFIC GRAVITY DETERMINATIONS ON SLAGS.

Slag	Laboratory A			Laboratory B			Laboratory C	Laboratory D			Laboratory E			General Average, Laboratories A, B, D and E
	Standard	Modified	Average	Standard	Modified	Average	Standard	Standard	Modified	Average	Standard	Modified	Average	
No. 1..	2.16	2.18	2.17	2.11	2.19	2.15	2.13	2.10	2.15	2.12	2.19	2.24	2.21	2.16
No. 2..	2.22	2.29	2.25	2.17	2.20	2.18	2.14	2.16	2.18	2.17	2.20	2.21	2.21	2.20
No. 3..	2.06	2.42	2.24	2.35	2.46	2.41	1.88	1.90	2.38	2.14	2.19	2.41	2.30	2.27
No. 4..	2.18	2.21	2.19	2.29	2.10	2.19	1.74	2.03	2.20	2.11	2.20	2.29	2.24	2.18
No. 5..	2.24	2.29	2.26	2.29	2.11	2.20	2.20	2.21	2.23	2.22	2.25	2.28	2.26	2.24
No. 6..	2.29	2.24	2.26	2.19	2.19	2.19	2.18	2.33	2.21	2.27	2.21	2.26	2.23	2.24
No. 7..	1.77	1.68	1.72	1.58	1.68	1.63	1.47	1.69	1.60	1.64	1.52	1.62	1.57	1.64
No. 8..	2.23	2.29	2.26	2.45	2.39	2.42	2.22	2.11	2.26	2.18	2.32	2.34	2.33	2.30
No. 9..	2.44	2.50	2.47	2.65	2.55	2.60	2.29	2.45	2.56	2.50	2 56	2.57	2.57	2.54
No. 10..	1.89	1.88	1.88	1.92	1.99	1.96	1.81	1.88	2.01	1.94	1.93	2.07	2.00	1.95
No. 11..	2.25	2.30	2.27	2.25	2.34	2.29	1.98	2.26	2.42	2.34	2.40	2.44	2.42	2.33
No. 12..	2.30	2.61	2.45	2.46	2.56	2.51	2.66	2.38	2.52	2.45	2.50	2.61	2.56	2.49
No. 13..	1.86	1.98	1.92	1.90	1.91	1.90	1.99	2.08	1.96	2.02	1.92	1.95	1.94	1.95
No. 14..	2.40	2.60	2.50	2.37	2.59	2.48	2.34	2.33	2.57	2.45	2.58	2.65	2.62	2.51
No. 15..	1.81	1.86	1.83	....	2.06	2.06	1.69	1.82	1.82	1.82	1.66	1.82	1.74	1.86
No. 16..	2.21	2.22	2.21	2.26	2.37	2.31	2.13	2.14	2.18	2.16	2.11	2.17	2.14	2.21
No. 17..	2.24	2.16	2.20	2.46	2.32	2.39	2.19	2.12	2.16	2.14	2.02	2.11	2.06	2.20
No. 18..	2.54	2.79	2.66	2.51	2.53	2.52	2.26	2.42	2.65	2.53	2.64	2.64	2.64	2.59
No. 19..	1.96	1.81	1.88	1.61	1.79	1.70	2.03	1.58	1.79	1.68	1.65	1.84	1.74	1.75
No. 20..	2.06	2.00	2.03	2.06	2.02	2.04	2.01	1.90	1.97	1.93	2.11	2.06	2.08	2.02
Average	2.16	2.21	2.18	2.20	2.22	2.21	2.07	2.09	2.19	2.14	2 16	2.23	2.19	2.18

Eight out of the eighteen materials studied showed more than 15 per cent standard abrasion loss, yet all of these slags gave entirely satisfactory strengths when placed in concrete. The four materials (Nos. 23, 25, 26 and 21) with next to the lowest compressive strength all showed more than 15 per cent abrasion loss. The concrete from these four materials, however, ranges only from 6 to 7 per cent below the average results obtained on all materials. Materials Nos. 2, 1 and 28 also show more than 15 per cent abrasion loss, yet these materials all give over 100 per cent compressive strength when placed in concrete, material No. 28 showing the highest strength of all slags studied.

Generally speaking, the extremely heavy slags (over 90 lb.) gave the poorest strengths. Definite conclusions are drawn from this series:

1. That all materials over 70 lb. per cu. ft. in weight gave satisfactory compressive strengths when placed in concrete.
2. That the standard abrasion test on slag aggregate is not a measure of the concrete-making properties of the material as indicated by the compressive strength of the concrete.

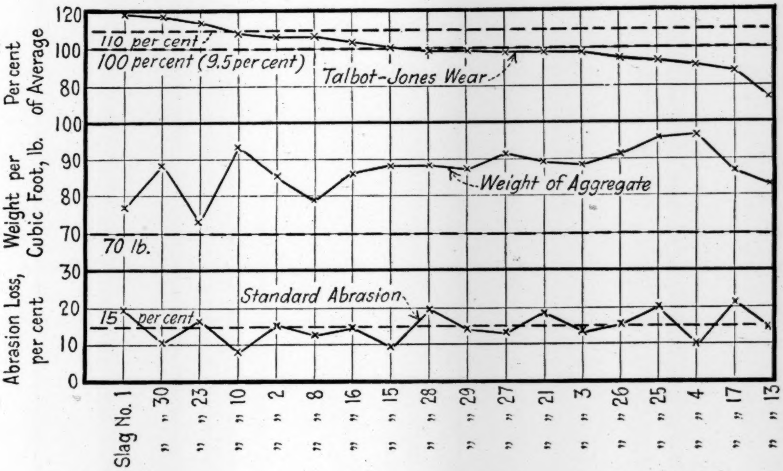

FIG. 6.—U. S. Bureau of Public Roads Tests, Based on Relative Wear Resistance.

Wear of Concrete.—Figure 6 shows the abrasion and weight tests on the aggregates and the relative value of the concrete as indicated by the Talbot-Jones wear test, plotted according to the decreasing relative wear of the concrete. A study of this figure shows that there were only three concretes with more than 10 per cent above the average wear. A 15-per-cent abrasion limit on the aggregate would eliminate two of these three materials, but would also eliminate six other materials which are satisfactory from the standpoint of wear.

Quite generally speaking, increase in the weight of the aggregate is accompanied by a decrease in the wear of the concrete. There are, however, several exceptions to this trend. The definite conclusion to be drawn from this chart is that the abrasion test on the aggregate is not a measure of the wear-resisting qualities of concrete made from these materials, since five of the eight slags which would be eliminated by a 15-per-cent standard abrasion loss produced concrete with less than the average wear.

Study of Results of Present Tests on Twenty Slags:

Compressive Strength.—Figure 7 shows standard and modified abrasion losses, compact weight per cubic foot and relative compressive strengths plotted in the order of ascending value of the compressive strength. The relative compressive strengths given are the average of 28-day and 90-day tests. A study of this figure shows that there are three concretes with less than 90 per cent relative strength value. These contain slags Nos. 7, 19 and 13, two of which, Nos. 7 and 19, would be eliminated by a 70-lb. per cu. ft. compact weight requirement. This same limit would also throw out slag No. 15, which shows a comparative strength of 96 per cent, indicating a satisfactory quality of concrete. A 15-per-cent standard abrasion limit would eliminate slags Nos. 7, 19 and 13, but this limit would also throw out slags Nos. 20, 15, 10 and 16, which show satisfactory concrete quality as measured by compression, No. 16 giving the third strongest concrete in the series. A 24-per-cent modified abrasion limit would eliminate slags Nos. 7 and 19, but would also throw out slags Nos. 10, 1, 16 and 17, all of which give satisfactory concrete

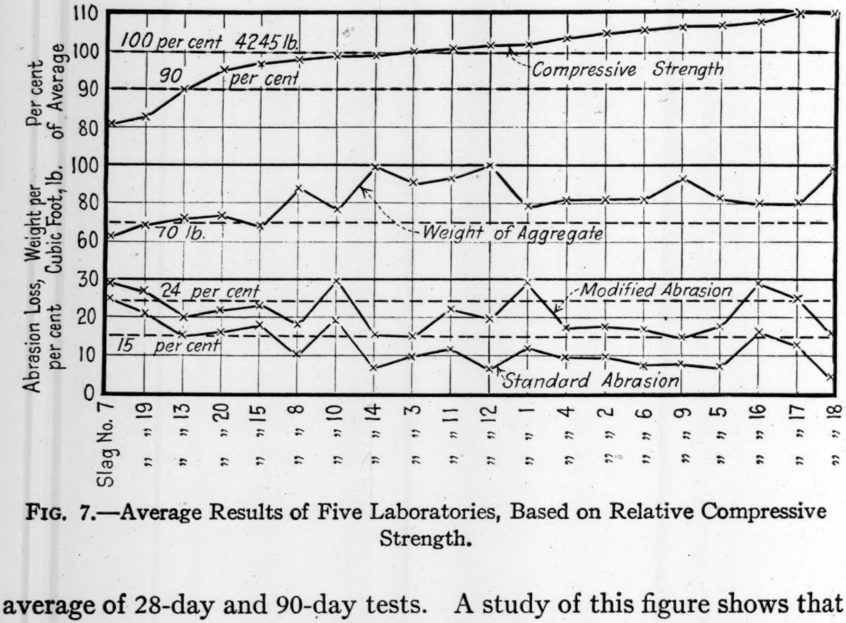

Fig. 7.—Average Results of Five Laboratories, Based on Relative Compressive Strength.

as indicated by compressive strength, Nos. 16 and 17 being next to the highest strength materials shown.

A 70-lb. compact weight per cubic foot requirement would eliminate two of the three materials which might be considered undesirable (under 90 per cent relative strength) and would eliminate one material having satisfactory compressive strength. A 15-per-cent standard abrasion limit would eliminate all three materials which might be considered unsatisfactory (under 90 per cent relative strength) but would also eliminate four satisfactory materials. The 24-per-cent modified abrasion limitation would eliminate two of the three unsatisfactory materials but would also eliminate four satisfactory materials.

TABLE X.—RESULTS OF ABSORPTION TESTS ON SLAGS.

Slag	Laboratory A	Laboratory B	Laboratory C	Laboratory D	Laboratory E	Average
TOTAL ABSORPTION, PER CENT BY WEIGHT						
No. 1	3.2	2.4	4.9	3.1	3.3	3.4
No. 2	2.3	2.6	2.9	3.2	3.4	2.9
No. 3	2.8	1.4	4.4	2.8	2.4	2.8
No. 4	3.0	2.2	6.3	3.5	3.5	3.7
No. 5	2.3	2.0	3.8	2.8	3.0	2.8
No. 6	2.0	1.4	3.9	2.2	3.2	2.5
No. 7	6.9	9.5	12.2	8.1	10.8	9.5
No. 8	2.8	1.5	4.9	3.0	3.5	3.1
No. 9	1.7	0.7	3.1	1.2	1.9	1.7
No. 10	3.6	1.5	6.1	3.5	3.7	3.7
No. 11	1.5	2.1	2.3	1.4	1.6	1.8
No. 12	1.1	0.5	1.7	0.7	0.8	1.0
No. 13	6.2	5.4	4.9	4.7	6.2	5.5
No. 14	1.1	1.5	3.2	1.4	1.0	1.6
No. 15	6.5	7.4	11.6	6.5	8.4	8.1
No. 16	2.3	4.1	2.8	2.8	4.3	3.3
No. 17	4.2	1.2	4.3	3.8	4.7	3.6
No. 18	1.1	1.1	2.3	0.8	0.8	1.2
No. 19	6.2	10.0	5.8	6.6	9.1	7.5
No. 20	4.9	6.3	6.0	6.3	5.7	5.8
Average	3.3	3.2	4.9	3.4	4.1	3.8
ABSORPTION AFTER 30 MINUTES' IMMERSION, PER CENT BY WEIGHT						
No. 1	1.5	2.2	...	2.0	2.5	2.0
No. 2	1.6	3.0	...	2.4	1.7	2.2
No. 3	1.9	1.5	...	1.0	1.4	1.4
No. 4	1.7	2.5	...	1.8	2.0	2.0
No. 5	1.0	2.0	...	2.0	1.6	1.6
No. 6	1.6	2.5	...	1.4	2.1	1.9
No. 7	6.3	7.9	...	7.8	6.0	7.0
No. 8	1.7	3.2	...	2.4	1.7	2.2
No. 9	0.8	1.0	...	1.0	0.7	0.9
No. 10	2.2	3.0	...	2.3	2.0	2.4
No. 11	1.0	2.2	...	1.1	0.8	1.3
No. 12	0.0	1.0	...	0.3	0.4	0.4
No. 13	5.8	5.0	...	3.6	2.9	4.3
No. 14	0.5	1.7	...	1.0	0.8	1.0
No. 15	3.4	4.0	...	5.2	3.8	4.1
No. 16	0.7	4.0	...	1.9	2.1	2.2
No. 17	2.0	2.9	...	2.4	1.8	2.3
No. 18	0.6	0.5	...	0.4	0.6	0.5
No. 19	5.0	7.1	...	4.7	5.5	5.6
No. 20	4.6	5.2	...	5.2	3.2	4.6
Average	2.2	3.1	...	2.5	2.2	2.5

The definite conclusion is therefore drawn from this figure that both the weight per cubic foot limitation and abrasion tests will eliminate undesirable materials as indicated by the compressive strength of the resulting concrete. The abrasion tests, however, will also eliminate a considerable number of entirely satisfactory materials while a 70-lb. weight per cubic foot requirement would eliminate only one satisfactory material. The weight per cubic foot, therefore, as indicated by these data is the better and more consistent method of determining the quality of the concrete as measured by compression tests which can be expected from various slags.

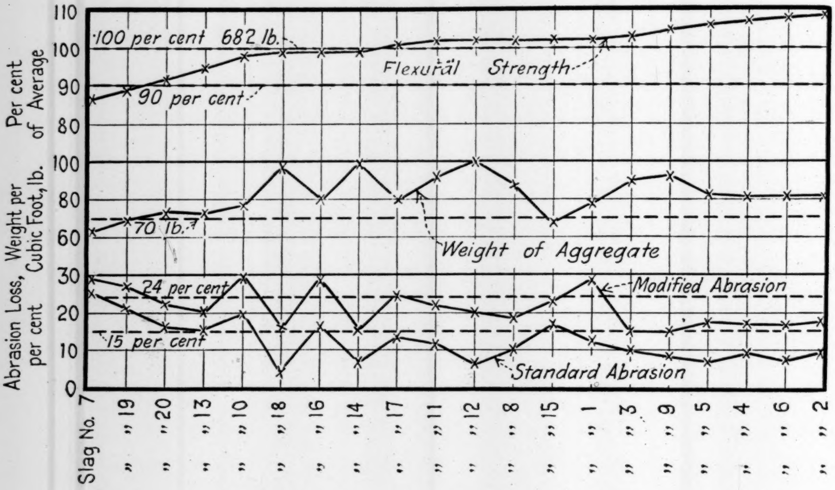

FIG. 8.—Average Results of Five Laboratories, Based on Relative Flexural Strength.

Flexural Strength.—Figure 8 shows standard and modified abrasion losses, weight per cubic foot and relative flexural strengths plotted in the ascending order of quality of the concrete as shown by relative flexural strengths. The transverse strengths given are the average of 28-day and 90-day tests.

The two materials showing unsatisfactory results (under 90 per cent relative strength), Nos. 7 and 19, would be eliminated by a 70-lb. compact weight requirement, which would also eliminate No. 15, having satisfactory flexural strength. Slags Nos. 7 and 19 would also be eliminated by both the 15-per-cent standard and 24-per-cent modified abrasion limitations. The 15-per-cent standard abrasion limit would, however, eliminate Nos. 20, 13, 10, 16 and 15, all of which show satisfactory flexural strengths. The 24-per-cent modified abra-

TABLE XI.—VOIDS, COMPUTED FROM SPECIFIC GRAVITY RESULTS AND LOOSE AND COMPACT WEIGHTS.

Slag	Laboratory A			Laboratory B			Laboratory C	Laboratory D			Laboratory E			General Average, Laboratories A, B, D and E
	Standard	Modified	Average	Standard	Modified	Average	Standard	Standard	Modified	Average	Standard	Modified	Average	
							COMPUTED FROM LOOSE WEIGHTS PER CUBIC FOOT							
No. 1..	46.5	47.0	46.8	47.8	49.7	48.8	....	44.2	45.5	44.9	47.6	48.8	48.2	47.2
No. 2..	45.8	47.5	46.7	45.3	46.1	45.8	....	44.3	44.8	44.6	47.2	47.5	47.4	46.1
No. 3..	36.9	46.3	41.6	46.1	48.6	47.4	....	29.1	43.4	36.3	42.2	47.5	44.9	42.6
No. 4..	44.8	45.6	45.2	51.3	46.9	49.1	....	40.0	44.7	42.3	46.5	48.6	47.5	46.0
No. 5..	46.3	47.5	46.9	48.2	43.8	46.0	....	45.0	45.5	45.2	47.5	48.2	47.7	46.5
No. 6..	48.2	47.0	47.6	48.4	48.4	48.4	....	47.4	44.6	46.0	48.2	49.3	48.7	47.7
No. 7..	45.7	42.7	44.2	42.9	46.3	44.6	....	45.2	42.1	43.7	44.3	47.7	46.0	44.6
No. 8..	44.6	46.1	45.4	46.5	45.2	45.9	....	40.6	44.5	42.5	45.7	46.2	46.0	44.9
No. 9..	44.1	45.5	44.8	50.2	48.3	49.3	....	44.6	47.0	45.8	47.9	48.1	48.0	47.0
No. 10..	41.4	41.1	41.2	46.5	48.4	47.4	....	39.6	43.5	41.5	42.3	46.2	44.3	43.6
No. 11..	39.4	40.7	40.0	45.1	47.2	46.1	....	38.7	42.7	40.7	42.8	43.7	43.3	42.5
No. 12..	37.2	44.7	41.0	41.2	43.5	42.4	....	39.4	42.7	41.1	43.2	45.6	44.4	42.2
No. 13..	41.4	44.9	43.2	46.2	46.5	46.3	....	48.4	45.3	46.9	50.2	51.0	50.6	46.8
No. 14..	39.8	44.5	42.2	39.9	45.0	42.5	....	38.2	43.9	41.1	45.2	46.6	45.9	42.9
No. 15..	46.9	48.3	47.6	....	53.5	53.5	....	47.4	47.4	47.4	44.6	49.5	47.1	48.9
No. 16..	46.3	46.5	46.4	50.0	52.4	51.2	....	44.7	46.1	45.4	47.0	48.4	47.7	47.7
No. 17..	47.7	45.8	46.8	54.3	51.6	53.0	....	44.6	45.7	45.1	44.8	47.2	46.0	47.7
No. 18..	41.9	47.1	44.5	45.7	46.1	45.9	....	38.6	42.0	40.3	46.1	46.1	46.1	44.2
No. 19..	50.1	46.0	48.0	42.9	48.7	45.8	....	35.8	43.4	39.6	44.3	49.8	47.0	45.1
No. 20..	47.8	46.3	47.1	48.6	47.6	48.1	....	42.2	44.2	43.2	50.2	49.0	49.5	47.0
Average	44.1	45.5	44.8	46.7	47.7	47.2	....	41.9	44.5	43.2	45.9	47.8	46.8	45.6
							COMPUTED FROM COMPACT WEIGHTS PER CUBIC FOOT							
No. 1..	42.8	43.3	43.1	40.6	42.7	41.7	40.5	40.0	41.4	40.7	40.9	42.4	41.6	41.8
No. 2..	40.8	42.6	41.7	39.6	40.5	40.0	39.3	38.2	38.8	38.5	39.7	39.8	39.8	40.0
No. 3..	32.2	42.3	37.3	38.5	41.3	39.9	19.8	23.4	38.8	31.1	34.2	40.0	37.1	36.4
No. 4..	41.1	41.9	41.5	45.0	40.0	42.5	22.6	34.8	39.8	37.3	38.4	40.9	39.6	40.2
No. 5..	41.3	42.6	41.9	42.6	37.7	40.2	38.8	40.3	40.9	40.6	39.9	40.7	40.3	40.7
No. 6..	42.6	41.3	41.9	41.0	41.0	41.0	38.2	43.8	40.8	42.3	40.0	41.2	40.6	41.4
No. 7..	42.0	38.9	40.5	36.0	39.8	37.9	30.2	40.0	36.7	38.3	33.9	37.8	35.9	38.1
No. 8..	40.3	41.9	41.1	42.6	41.1	41.9	32.8	35.3	39.5	37.4	37.3	38.0	37.7	39.5
No. 9..	39.5	41.0	40.3	45.4	43.3	44.4	33.5	39.5	42.0	40.7	40.0	40.0	40.0	41.4
No. 10..	36.3	36.0	36.1	37.8	40.0	38.9	28.3	34.2	38.5	36.4	33.5	38.1	35.8	36.8
No. 11..	34.4	35.8	35.1	36.4	38.9	37.6	23.9	34.1	38.5	36.3	36.0	37.1	36.5	36.4
No. 12..	33.1	41.0	37.1	35.8	38.3	37.1	37.3	33.8	37.4	35.6	34.8	37.8	36.3	36.5
No. 13..	36.2	40.1	38.2	40.9	41.2	41.0	40.4	43.3	39.9	41.6	41.9	42.7	42.3	40.8
No. 14..	35.8	40.8	38.4	31.7	37.5	34.6	30.1	33.3	39.5	36.4	38.9	40.4	39.7	37.3
No. 15..	41.5	43.1	42.3	....	48.4	48.4	29.8	41.9	41.9	41.9	35.5	41.1	38.3	42.7
No. 16..	41.2	41.5	41.4	44.8	47.4	46.1	39.8	40.6	41.6	41.1	39.8	41.4	40.6	42.3
No. 17..	43.5	41.4	42.4	49.1	46.0	47.6	39.9	39.0	40.2	39.6	37.4	39.7	38.6	42.1
No. 18..	37.5	43.1	40.3	40.4	40.9	40.7	31.2	33.3	39.0	36.1	38.8	38.8	38.8	39.0
No. 19..	44.4	39.8	42.1	34.3	40.9	37.6	40.0	30.6	38.7	34.7	34.8	41.1	38.0	38.2
No. 20..	42.4	40.7	41.5	43.9	42.8	43.4	43.3	37.6	39.8	38.7	42.8	41.6	42.2	41.4
Average	39.4	41.0	40.2	40.3	41.5	41.0	34.0	36.8	39.7	38.3	37.9	40.0	39.0	39.7

sion limit would also eliminate materials Nos. 10, 16, 17 and 1, all of which show satisfactory results in concrete. The data of Fig. 8 are quite similar to those of Fig. 7 in that all materials showing less than 90 per cent relative strength would be eliminated by a 70-lb. compact weight requirement and by a 15-per-cent standard or 24-per-cent modified abrasion limitation. The 70-lb. weight requirement would eliminate only one satisfactory material while the 15-per-cent standard abrasion limit would eliminate five satisfactory materials and the 24-per-cent modified abrasion limit would eliminate four satisfactory materials. The logical conclusion as shown by these data is, therefore, that the weight per cubic foot of the aggregate is the better criterion for predicting the quality of the concrete as measured by flexural strength.

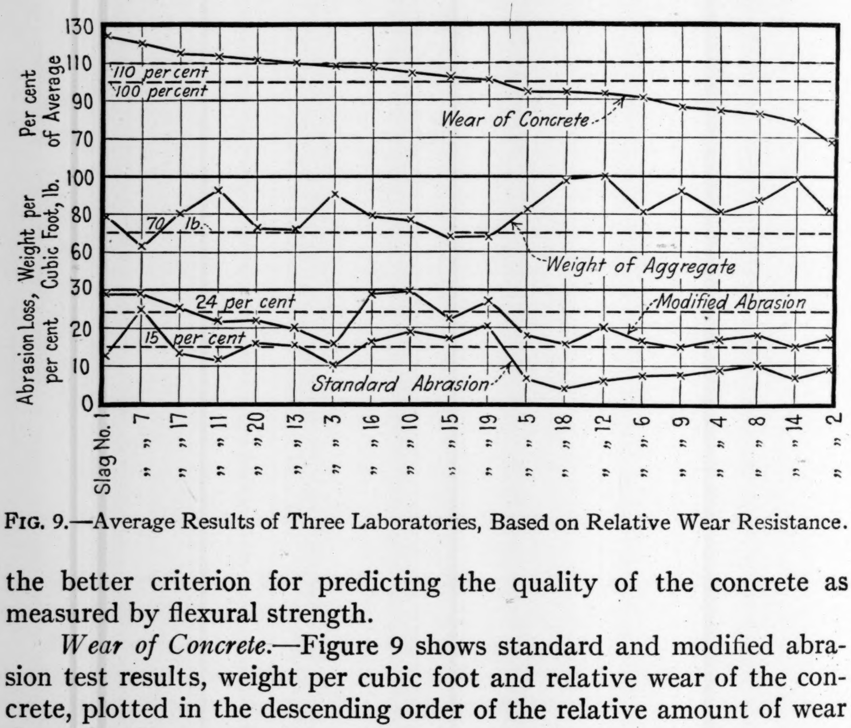

FIG. 9.—Average Results of Three Laboratories, Based on Relative Wear Resistance.

Wear of Concrete.—Figure 9 shows standard and modified abrasion test results, weight per cubic foot and relative wear of the concrete, plotted in the descending order of the relative amount of wear shown by the concrete.

Three laboratories reported wear tests of the concrete. No definite method was given for making this test and two of the laboratories reported that they developed no satisfactory wear results. A study of the details submitted by the three laboratories which reported indicates very erratic, unsatisfactory results on the same material. It will be noted that the relative wear values cover a very much greater range than either the compressive strength or flexural

TABLE XII.—WATER-CEMENT RATIO, SLUMP, AND FLOW OF CONCRETE.

Slag	Laboratory A			Laboratory B		Laboratory C		Laboratory D			Laboratory E			Average		
	Water-Cement Ratio[a]	Slump, in.	Flow	Water-Cement Ratio[a]	Slump, in.	Water-Cement Ratio[a]	Slump, in.	Water-Cement Ratio[a]	Slump, in.	Flow	Water-Cement Ratio[a]	Slump, in.	Flow	Water-Cement Ratio[a]	Slump, in.	Flow
No. 1	0.79	2	132	....	..	0.70	$2\frac{1}{2}$	0.76	2	168	0.75	$1\frac{3}{4}$	168	0.75	2	156
No. 2	0.81	$1\frac{3}{4}$	132	0.59	$2\frac{1}{2}$	0.67	2	0.75	$2\frac{1}{4}$	171	0.75	$2\frac{1}{2}$	178	0.71	$2\frac{1}{4}$	160
No. 3	0.76	2	134	....	..	0.74	$1\frac{3}{4}$	0.79	2	174	0.75	$2\frac{1}{4}$	182	0.76	2	163
No. 4	0.79	2	134	0.56	$2\frac{3}{4}$	0.84	$1\frac{3}{4}$	0.76	2	170	0.75	$2\frac{3}{4}$	184	0.74	$2\frac{1}{4}$	163
No. 5	0.81	2	134	0.56	$2\frac{1}{2}$	0.87	$1\frac{3}{4}$	0.76	$2\frac{1}{4}$	174	0.75	$2\frac{1}{4}$	175	0.75	$2\frac{1}{4}$	161
No. 6	0.78	2	134	0.50	$1\frac{3}{4}$	0.74	$1\frac{5}{8}$	0.77	$1\frac{1}{2}$	160	0.75	$2\frac{3}{4}$	173	0.71	2	156
No. 7	0.77	$1\frac{3}{4}$	132	....	..	0.73	$1\frac{1}{2}$	0.66	$1\frac{3}{4}$	156	0.75	$2\frac{1}{4}$	174	0.73	$1\frac{3}{4}$	154
No. 8	0.82	2	132	....	..	0.80	$1\frac{3}{4}$	0.76	$1\frac{3}{4}$	162	0.75	$2\frac{1}{2}$	174	0.78	2	156
No. 9	0.80	2	132	0.54	2	0.85	$1\frac{3}{4}$	0.78	$2\frac{1}{2}$	176	0.75	2	171	0.74	2	160
No. 10	0.79	2	136	0.52	$1\frac{3}{4}$	0.77	2	0.74	$2\frac{1}{4}$	172	0.75	$2\frac{1}{2}$	172	0.71	2	160
No. 11	0.80	2	135	....	..	0.84	$1\frac{7}{8}$	0.78	$2\frac{1}{2}$	175	0.75	2	172	0.79	2	161
No. 12	0.83	2	141	0.62	$2\frac{1}{2}$	0.74	$1\frac{1}{2}$	0.80	$2\frac{1}{2}$	179	0.75	$2\frac{1}{2}$	175	0.75	$2\frac{1}{4}$	165
No. 13	0.69	$1\frac{3}{4}$	131	0.67	$2\frac{1}{2}$	0.74	$1\frac{3}{4}$	0.77	$1\frac{3}{4}$	154	0.75	2	170	0.72	2	152
No. 14	0.82	2	137	....	..	0.77	$1\frac{3}{4}$	0.76	$1\frac{3}{4}$	175	0.75	2	175	0.77	2	162
No. 15	0.81	2	133	0.53	2	0.74	$1\frac{3}{4}$	0.72	$1\frac{1}{2}$	170	0.75	2	170	0.71	$1\frac{3}{4}$	158
No. 16	0.83	2	136	....	..	0.76	2	0.78	$1\frac{1}{2}$	170	0.75	$2\frac{1}{4}$	176	0.78	2	161
No. 17	0.82	2	138	....	..	0.78	2	0.77	$2\frac{1}{2}$	176	0.75	$2\frac{1}{2}$	172	0.78	$2\frac{1}{4}$	162
No. 18	0.81	$2\frac{1}{4}$	139	0.68	$2\frac{1}{2}$	0.81	2	0.80	$1\frac{3}{4}$	167	0.75	$2\frac{1}{4}$	175	0.77	$2\frac{1}{4}$	160
No. 19	0.75	$1\frac{3}{4}$	125	0.66	2	0.67	$1\frac{1}{2}$	0.76	$1\frac{3}{4}$	148	0.75	2	170	0.72	$1\frac{3}{4}$	148
No. 20	0.72	$1\frac{1}{2}$	123	0.64	2	....	..	0.69	$1\frac{3}{4}$	143	0.75	$2\frac{1}{4}$	172	0.70	2	146
Average	0.79	2	133	0.59	$2\frac{1}{4}$	0.77	$1\frac{3}{4}$	0.76	2	167	0.75	$2\frac{1}{4}$	174	0.74	2	158

[a] Net water-cement ratio after deducting the absorption of the aggregate after 30 minutes immersion.

TABLE XIII.—RESULTS OF WEAR TESTS ON CONCRETE.

Slag	Laboratory A	Laboratory B		Laboratory C		Laboratory D	Laboratory E		Per Cent of Average, All Laboratories, All Slags
		Wear, per cent loss by weight	Per Cent of Average, All Slags	Depth of Wear, in.	Per Cent of Average, All Slags		Depth of Wear, in.	Per Cent of Average, All Slags	
No. 1	..	4.58	125	0.29	126	..	0.086	121	124
No. 2	..	3.11	85	0.09	39	..	0.058	82	69
No. 3	..	3.89	106	0.23	100	..	0.086	121	109
No. 4	..	3.38	92	0.19	83	..	0.058	82	86
No. 5	..	2.91	79	0.24	104	..	0.073	103	95
No. 6	..	3.95	108	0.15	65	..	0.073	103	92
No. 7	..	3.58	97	0.30	130	..	0.096	135	121
No. 8	..	3.72	101	0.15	65	..	0.060	85	84
No. 9	..	2.78	76	0.16	70	..	0.082	115	87
No. 10	..	3.90	106	0.28	122	..	0.062	87	105
No. 11	..	3.35	91	0.30	130	..	0.085	120	114
No. 12	..	3.53	96	0.16	70	..	0.082	115	94
No. 13	..	4.53	123	0.33	143	..	0.046	65	110
No. 14	..	3.02	82	0.17	74	..	0.059	83	80
No. 15	..	1.92	52	0.38	165	..	0.066	93	103
No. 16	..	4.49	122	0.25	109	..	0.065	92	108
No. 17	..	3.59	98	0.27	117	..	0.093	131	115
No. 18	..	2.75	75	0.22	96	..	0.081	114	95
No. 19	..	5.10	139	0.23	100	..	0.048	68	102
No. 20	..	5.39	147	0.26	113	..	0.055	77	112
Average	..	3.67	100	0.23	100	..	0.071	100	100

strength results, only ten of the materials coming within a 10-per-cent range above or below the average of 100 per cent. The concrete showing the greatest amount of wear was 24 per cent above the average and was made from slag No. 1.

A 70-lb. weight per cubic foot limitation would discard one of the materials showing excessive wear (more than 10 per cent above the average) but would also eliminate two materials showing very low wear. The 15-per-cent standard abrasion limit would eliminate two materials showing high wear but would also eliminate five materials with satisfactory wearing qualities. The 24-per-cent modified abrasion limit would eliminate three materials showing unsatisfactory wear, but would also eliminate three materials showing satisfactory wear.

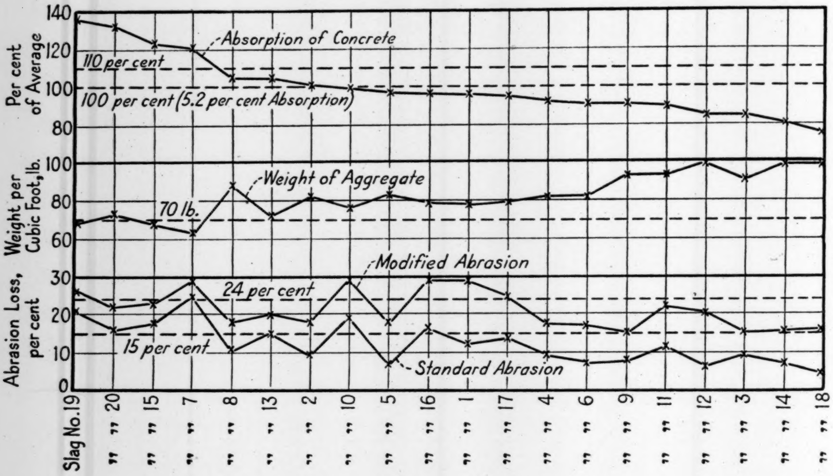

FIG. 10.—Average Results of Five Laboratories, Based on Relative Absorption.

From the results as indicated by this chart no definite conclusions can be drawn other than the fact that neither weight per cubic foot, standard abrasion nor modified abrasion predicts in any way the wear to be expected in the concrete. Very generally speaking, the concrete containing heavy slags (over 80 lb.) gave the least wear, although the erratic results obtained would indicate that the methods used for making the wear tests were not dependable.

Absorption of Concrete.—Figure 10 shows the standard and modified abrasion test results, compact weight per cubic foot of the coarse aggregate and the quality of the concrete as measured by absorption, plotted in the order of decreasing relative absorption. A study of this figure shows that, generally, the lighter weight slags produce concrete having higher absorption.

A required weight of 70-lb. per cubic foot would eliminate three out of the four concretes showing more than 10 per cent above the average absorption. A 15-per-cent abrasion loss limitation would eliminate all four of the concretes showing more than 10 per cent above the average absorption, but would also eliminate three other materials which give very good absorption results. A 24-per-cent modified abrasion limitation would eliminate two of the four unsatisfactory materials but would also eliminate four others which showed satisfactory absorption results in concrete. Conclusions drawn from this study of the results on the absorption of concrete are:

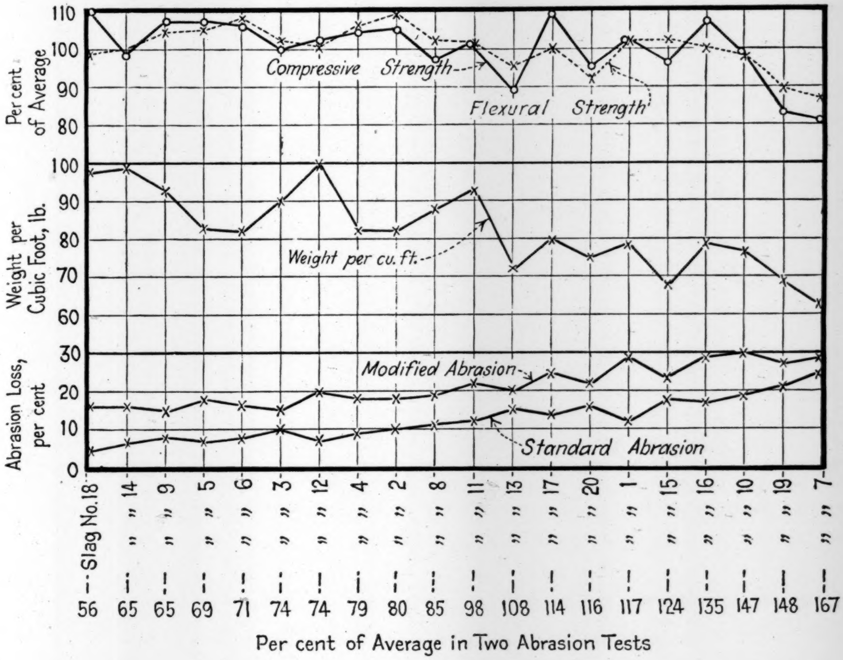

FIG. 11.—Average Results of Five Laboratories, Plotted According to Composite Abrasion Factor.

1. That the abrasion losses do not conform in any logical way to the absorption of the concrete.

2. That the weight per cubic foot of the aggregate is a very good criterion of the results which may be expected from the actual absorption of the concrete.

Comparison of Abrasion Loss and Compressive and Flexural Strengths of Concrete.—In Fig. 11 are plotted the compact weight per cubic foot, the standard and modified abrasion test results and the relative compressive and flexural strengths of the concrete, plotted in order of ascending values of abrasion loss. In establishing the order of plotting, the slags were arranged in the order of the average of their standard and modified abrasion losses, so that the chart is based on a composite abrasion factor representing both abrasion tests. The points in the standard abrasion and modified abrasion lines, however, are actual abrasion losses for each test. This figure shows a striking concordance between the relative compressive strengths and the relative flexural strengths, and that, generally, the abrasion losses increase as the weights per cubic foot decrease. Conclusions from the data shown by this chart are:

TABLE XIV.—RESULTS OF ABSORPTION TESTS OF CONCRETE.

Slag	Laboratory A		Laboratory B		Laboratory C		Laboratory D		Laboratory E		Average	
	Absorption, per cent by weight	Per Cent of Average, All Slags	Absorption, per cent by weight	Per Cent of Average, All Slags	Absorption, per cent by weight	Per Cent of Average, All Slags	Absorption, per cent by weight	Per Cent of Average, All Slags	Absorption, per cent by weight	Per Cent of Average, All Slags	Absorption, per cent by weight	Per Cent of Average, All Slags
No. 1	6.25	94	2.74	75	7.1	104	5.9	98	5.89	96	5.58	95
No. 2	6.20	93	4.79	131	6.2	91	6.1	102	6.36	104	5.93	101
No. 3	6.12	92	2.23	61	5.6	82	5.3	88	5.67	92	4.98	85
No. 4	6.26	94	2.25	61	7.7	113	5.5	92	5.26	86	5.39	92
No. 5	6.21	93	3.65	99	6.6	97	5.9	98	6.18	101	5.71	97
No. 6	6.79	102	1.88	51	6.1	90	5.5	92	6.48	106	5.35	91
No. 7	7.70	116	3.31	90	8.6	126	8.1	135	7.91	129	7.12	122
No. 8	6.92	104	4.62	126	7.0	103	6.4	107	5.84	95	6.16	105
No. 9	6.63	100	2.89	79	6.5	96	5.5	92	5.09	83	5.32	91
No. 10	6.94	104	3.11	85	7.1	104	5.9	98	5.94	97	5.80	99
No. 11	6.23	94	2.26	62	7.1	104	5.6	93	5.34	87	5.31	91
No. 12	5.76	87	3.51	96	5.6	82	4.9	82	5.05	82	4.96	85
No. 13	7.40	111	3.56	97	6.6	97	6.3	105	6.89	112	6.15	105
No. 14	5.43	82	2.07	56	5.7	84	5.4	90	5.13	84	4.75	81
No. 15	7.77	117	7.11	194	6.7	99	7.2	120	7.54	123	7.26	124
No. 16	5.46	82	4.61	126	6.5	96	5.7	95	6.20	101	5.69	97
No. 17	6.85	103	2.76	75	6.6	97	5.9	98	5.65	92	5.55	95
No. 18	5.18	78	2.42	66	5.6	82	4.7	78	4.41	72	4.46	76
No. 19	9.17	138	5.68	155	8.4	124	8.0	113	8.61	141	7.97	136
No. 20	7.84	118	7.99	218	9.2	135	6.8	133	7.20	117	7.81	133
Average	6.65	100	3.67	100	6.8	100	6.0	100	6.13	100	5.86	100

1. That, generally, the quality of concrete as indicated by compression tests is the same as that indicated by flexure tests.

2. That the quality of the concrete is indicated more definitely by the unit weight than by the abrasion losses of the aggregate.

SUITABILITY OF THE ABRASION AND UNIT WEIGHT TESTS

Results of Tests by Seventeen Laboratories.—Figure 12 and Table I show the results of weight per cubic foot and abrasion tests made by seventeen laboratories on identical samples of each of four different slags. Figure 12 shows the maximum and mean variations of the results of all laboratories, plotted according to the mean variations in weight.

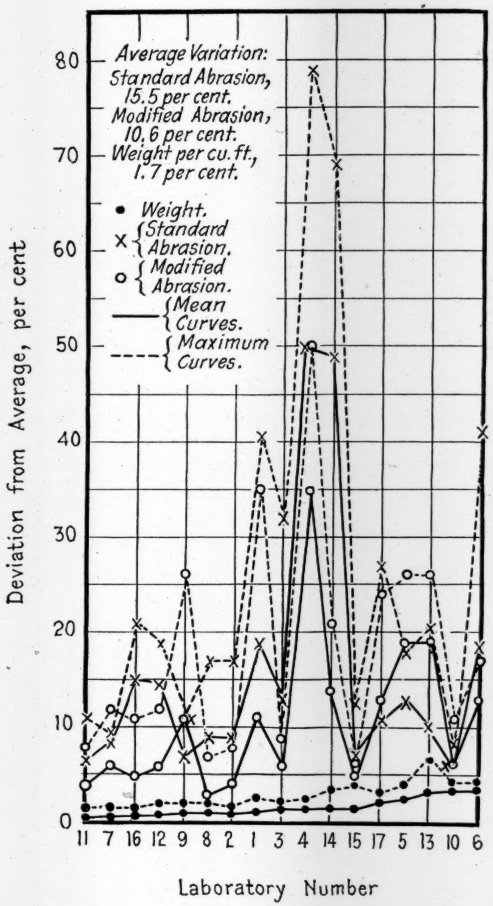

FIG. 12.—Comparison of Mean and Maximum Variations from Average Weight and Abrasion of Four Slags, Tested in Seventeen Laboratories, Based on Ascending Mean Variation in Weight.

It will be noted that all laboratories checked the unit weights on the four slags very accurately, with an average mean variation of 1.7 per cent and an average maximum variation of 2.8 per cent, the greatest individual variation from the average being 6.7 per cent. Entirely different results, however, were obtained in the abrasion tests, there being a striking inability on the part of individual laboratories to check in any reasonable degree the results obtained at other laboratories. The standard abrasion test results showed an average mean variation of 15.5 per cent and an average maximum variation of 25.4 per cent, the greatest individual variation from the average being 78.7 per cent. The modified abrasion test results showed an average mean variation of 10.7 per cent and an average maximum

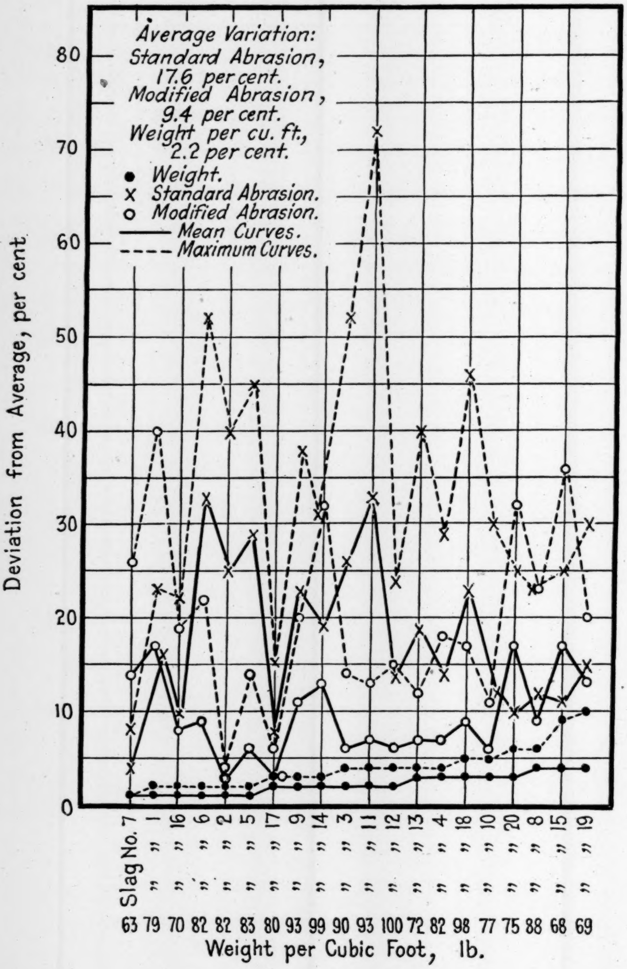

FIG. 13.—Comparison of Mean and Maximum Variations from Average Weight and Abrasion of Twenty Slags, Tested in Five Laboratories, Based on Ascending Mean Variation in Weight.

variation of 25.4 per cent, the greatest individual variation from the average being 49.6 per cent.

TABLE XV.—RESULTS OF COMPRESSION TESTS OF CONCRETE.

Slag	Laboratory A		Laboratory B		Laboratory C		Laboratory D		Laboratory E		Average	
	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags
28-DAY STRENGTHS												
No. 1	3700	105	4275	102	3020	100	3940	104	4798	98	3947	102
No. 2	3590	102	4580	109	3510	117	3890	103	4554	93	4025	105
No. 3	3500	100	4285	102	2940	98	3970	105	4975	101	3934	101
No. 4	3780	107	3913	93	3070	102	4210	111	5103	104	4015	103
No. 5	3530	100	5500	131	2640	88	4070	107	5266	107	4201	107
No. 6	3630	103	4307	103	3380	112	3960	104	4988	102	4053	105
No. 7	2910	83	3143	75	2630	88	3190	84	4098	84	3194	83
No. 8	3560	101	3953	94	2650	88	3640	96	4908	100	3742	96
No. 9	3630	103	5078	121	2970	99	3710	98	5349	109	4147	106
No. 10	3480	99	4735	113	2770	92	3660	96	4934	101	3916	100
No. 11	3470	99	4687	112	2760	92	3840	101	5297	108	4011	102
No. 12	3510	100	4577	109	2660	88	3660	96	5280	108	3937	100
No. 13	3490	99	3165	76	2860	95	3280	86	4281	87	3415	89
No. 14	3570	102	3468	83	2800	93	4040	107	5417	110	3859	99
No. 15	3510	100	4217	101	2920	97	3800	100	4286	87	3747	97
No. 16	3690	105	4377	104	3660	122	3990	105	5278	108	4199	109
No. 17	3430	98	4617	110	3670	122	4230	112	4689	96	4127	108
No. 18	3300	94	4717	112	3750	125	4170	110	5353	109	4258	110
No. 19	3350	95	2865	68	2660	88	3070	81	4261	87	3241	84
No 20	3710	105	3517	84	2850	95	3540	93	4952	101	3714	96
Average	3517	100	4199	100	3009	100	3793	100	4903	100	3883	100
90-DAY STRENGTHS												
No. 1	4940	108	4988	103	3200	93	4890	110	5348	94	4673	102
No. 2	4520	99	5523	114	3670	108	4640	104	5845	103	4840	105
No. 3	4730	104	4653	96	3320	96	4590	103	5373	94	4533	99
No. 4	4680	102	4890	101	3610	104	4900	110	5982	105	4812	104
No. 5	4850	106	6102	126	3250	94	4800	108	5828	102	4966	107
No. 6	4550	100	5335	110	3760	109	4970	111	5728	101	4869	106
No. 7	3760	82	3633	75	2850	82	3390	76	4540	80	3635	79
No. 8	4710	103	4640	96	2940	85	4580	103	6229	109	4620	99
No. 9	4680	102	5810	120	3580	103	4660	105	6092	107	4964	107
No. 10	4400	96	4703	97	2970	86	4350	98	6525	115	4590	98
No. 11	4360	95	5507	113	2870	83	4280	96	6338	111	4671	100
No. 12	4490	98	5297	109	3360	97	4380	98	6612	116	4828	104
No. 13	4460	98	3642	75	3190	92	4040	91	5530	97	4172	91
No. 14	4850	106	4383	90	3120	90	4630	104	6061	106	4609	99
No. 15	4460	98	4538	94	3480	101	4340	97	5231	92	4410	96
No. 16	5220	114	5115	105	4090	118	4410	99	5228	92	4813	106
No. 17	4840	106	5410	111	4800	139	4600	103	5537	97	5037	111
No. 18	4670	102	4865	100	4630	134	4850	109	5950	104	4993	110
No. 19	3830	84	3495	72	3220	93	3640	82	4600	81	3757	82
No. 20	4380	96	4529	93	3280	95	4210	94	5338	94	4347	94
Average	4569	100	4853	100	3459	100	4459	100	5696	100	4607	100

From the results of these tests very definite conclusions are drawn:

1. That the weight per cubic foot determination is an accurate test which enables individual laboratories to check very closely the results obtained by other laboratories.

2. That the abrasion test on blast-furnace slag is unreliable and inaccurate in that it does not permit individual laboratories to check within reasonable limits the results obtained by other laboratories.

TABLE XVI.—RESULTS OF FLEXURE TESTS OF CONCRETE.

Slag	Laboratory A		Laboratory B		Laboratory C		Laboratory D		Laboratory E		Average	
	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags	Lb. per sq. in.	Per Cent of Average, All Slags
						28-DAY STRENGTHS						
No. 1	618	105	638	85	560	114	675	107	738	103	646	103
No. 2	562	96	830	110	635	130	646	103	705	100	676	108
No. 3	572	97	777	103	497	101	635	101	796	113	655	103
No. 4	634	108	940	125	466	95	664	106	842	119	709	111
No. 5	642	109	740	98	400	82	682	108	804	114	654	102
No. 6	652	111	850	113	510	104	702	112	709	101	685	108
No. 7	521	89	508	67	435	89	592	94	663	94	544	87
No. 8	652	111	778	103	460	94	660	105	663	94	643	101
No. 9	613	105	928	123	460	94	609	97	663	94	655	103
No. 10	642	109	655	87	397	81	600	95	730	104	605	95
No. 11	533	91	942	125	510	104	646	103	633	90	653	103
No. 12	538	92	795	105	560	114	624	100	721	102	648	103
No. 13	552	94	603	80	472	96	595	95	667	94	578	92
No. 14	557	95	837	111	460	94	607	97	679	96	628	99
No. 15	593	101	803	106	560	114	586	93	642	91	637	101
No. 16	648	110	785	104	483	99	617	98	705	100	648	102
No. 17	559	95	838	111	500	100	636	101	705	100	648	101
No. 18	545	93	790	105	490	100	629	100	709	101	633	100
No. 19	537	91	500	66	522	107	550	87	638	90	549	88
No. 20	565	96	573	76	432	88	618	98	688	98	575	91
Average	587	100	755	100	490	100	629	100	705	100	633	100
						90-DAY STRENGTHS						
No. 1	....	...	860	94	605	104	671	97	817	111	738	101
No. 2	....	...	1027	113	742	127	682	99	738	100	797	110
No. 3	....	...	997	109	592	102	633	91	771	105	748	102
No. 4	....	...	912	100	605	104	650	94	800	109	742	102
No. 5	....	...	1164	128	542	93	716	103	821	111	811	109
No. 6	....	...	1098	121	630	108	758	110	671	91	789	108
No. 7	....	...	735	81	517	89	587	85	650	88	622	86
No. 8	....	...	953	105	592	102	712	103	734	100	748	102
No. 9	....	...	1068	117	530	91	746	108	792	107	784	106
No. 10	....	...	1037	114	505	87	706	102	717	97	741	100
No. 11	....	...	852	94	617	106	767	111	654	89	722	100
No. 12	....	...	722	79	680	117	745	108	705	96	713	100
No. 13	....	...	822	90	542	93	730	105	717	97	703	96
No. 14	....	...	957	105	555	95	695	100	742	101	737	100
No. 15	....	...	923	101	667	114	691	100	709	96	748	103
No. 16	....	...	882	97	536	92	693	100	725	98	709	97
No. 17	....	...	918	101	546	94	691	100	780	106	734	100
No. 18	....	...	823	90	523	90	709	102	771	105	707	97
No. 19	....	...	655	72	592	102	589	85	750	102	647	90
No. 20	....	...	820	90	533	91	666	96	675	92	674	92
Average	....	...	911	100	583	100	692	100	737	100	731	100

Results Obtained in Present Investigation—Five Laboratories.—Figure 13 and Tables VII and VIII show results obtained by five cooperating laboratories on slags from twenty sources. Figure 13 shows the mean and maximum variations of the results on all twenty slags plotted according to the mean variations in weight.

Again, all laboratories checked the unit weight of slag very closely, the average mean variation being 2.2 per cent and the average maximum variation, 4.0 per cent, the greatest individual variation from the average being 10 per cent. In the standard Deval abrasion test results there was an average mean variation of 17.6 per cent and an average maximum variation of 33.5 per cent, the greatest individual variation from the average being 72 per cent.

The modified abrasion test results showed an average mean variation of 9.4 per cent and an average maximum variation of 19.7 per cent, the greatest individual variation from the average being 40 per cent.

Thus the degree of concordance obtained in this series of tests was about the same as that shown by the seventeen cooperating laboratories and the same general conclusion is drawn: That the unit weight of blast-furnace slag can be checked by various laboratories with a reasonable degree of concordance, while the abrasion test does not produce uniform and concordant test results.

Respectfully submitted on behalf of the section,

FRED HUBBARD,
Chairman.

APPENDIX VII

STUDY OF METHODS FOR DETERMINING MOISTURE IN SAND

By S. H. Graf[1] and R. H. Johnson[2]

Synopsis

The amount of moisture that a sand contains is of importance in concrete proportioning. The strength of the concrete is a function of the water-cement ratio and it is, therefore, necessary to take account of all the water in the mixture.

This paper presents data regarding methods for determining the moisture in sands, and points out some advantages and disadvantages that the different methods and some suggested modifications of them appear to have. Conclusions are drawn from the observed data indicating the comparative accuracy, simplicity of operation, and amount of apparatus needed.

Introduction

The more commonly used methods for the determination of water in sands have been well treated in a paper by W. R. Johnson presented before the American Concrete Institute in 1929.[3]

In the work covered here it was not intended to advance the comparison of the methods covered in the paper mentioned above but to study new methods, or to improve the old ones now in use. The more commonly used methods were tried and compared in order to obtain results to be used as a reference for improvements, or to serve as a foundation for the evolved methods.

Methods Studied

The following methods of determining moisture in sands were compared and tested on sands of known moisture contents:

Method 1.—Drying to constant weight in oven;
Method 2.—Drying to constant weight with denatured alcohol;
Method 3.—Distillation method using A.S.T.M. still head (Standard Method D 95);[4]
Method 4.—Displacement method using A.S.T.M. flask (Tentative Method C 70 - 28 T);[5]

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[3] "Comparison of Methods of Determining Moisture in Sands," *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 261 (1929).

[4] See Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 28), 1928 Supplement to Book of A.S.T.M. Standards, p. 148.

[5] See Tentative Method of Test for Field Determination of Surface Moisture in Fine Aggregate (C 70 - 28 T), *Proceedings*, Vol. 28, Part I, p. 832; also 1929 Book of A.S.T.M. Tentative Standards, p. 217.

Method 5.—Specific gravity method using sodium chloride solution;
Method 6.—Specific gravity method using magnesium sulfate solution;
Method 7.—Specific gravity method using calcium chloride solution;
Method 8.—Specific gravity method using zinc chloride solution;
Method 9.—Colorimetric methods using copper sulfate, in neutral, weakly acid, and strongly acid solutions;
Method 10.—Colorimetric method using phenolphthalein in water;
Method 11.—Colorimetric method using phenolphthalein in ethyl alcohol;
Method 12.—Electrical resistance method using salt solution;
Method 13.—Pearson method for absorbed moisture, using a Mason jar.

The first three of the above methods determine the total moisture. The water in all three methods is removed by heat, but in the third case it is collected again and measured directly, while in the first two the loss in weight of the sample is taken as the measurement of the removed water.

The distillation method using the A.S.T.M. still head (Standard Method D 95) is based on the collection of water vapors, driven off from a known weight of sample, by condensing them, and measuring the liberated water under a volatile mineral oil such as toluene. For the determination of the water in sands, as well as in almost any other material, this method is simple and ranks high in accuracy.

The displacement method using the A.S.T.M. flask (Tentative Method C 70 - 28 T), consists in finding the difference in the amount of water displaced by a damp sample and of a dry sample of the same weight. This method necessitates the drying of a sample of the sand as a control. It is highly adaptable to determining displacement differences; but, if the samples tested are from different sources, the necessity of drying a control sample for each increases the time over that of simple oven drying.

The specific gravity methods depend upon the change of specific gravity with dilution of an inorganic salt solution. These methods indicate only the surface moisture, the change of specific gravity being a direct function of the percentage dilution. The addition of a surface-dry (calcium-chloride-dried) sand has, from experiment, no noticeable effect on the solutions, with a possible exception of the zinc chloride. All measurements of the specific gravity were made by the Westphal balance. Then a hydrometer, (accurate to the third decimal place) was used on them as a check on the advisability of using the commercial hydrometers.

The colorimetric methods depend on the change in color with dilution of the colored solutions. These methods require a larger number of manipulations, due to the necessity of filtering the test solutions. The colloidal material in the sand and the selective absorption of the filter paper may cause a variable error, while the soluble material may influence the ion or molecular arrangement of the dissolved coloring material. The use of phenolphthalein offers a cheap coloring material, but the amount of the dye necessary to just obtain a maximum color without excess dye is very critical and in the range of practical moisture contents the method proves insensitive.

The electrical resistance method is based on the change in conductance of an ionic solution on dilution. The differences are small, for the increased ionization and activity of the dissolved material tends to balance the possible change due to dilution. Also, any colloidal material has a marked and variable effect on the conductance of a solution.

Surface-dry sand will not adhere to the sides of a glass vessel. This fact has been suggested by Mr. J. C. Pearson as a basis for determining when a sand is surface dry. When the fine sand particles just cease to adhere to the sides of the glass vessel, the sand is said to be surface dry. At this point the sand still contains a slightly greater moisture content than the calcium-chloride-dried sands used as reference standards in this work.

PROCEDURE

Preliminary Tests.—In determining the moisture content of sands, the absorbed moisture (Table I) in the sand was found, in order that the methods of determining the surface moisture could be checked by the oven-drying results. The surface-dry sand was obtained by keeping the sand for the tests confined over calcium chloride. After three or four days this sand did not materially change in weight with time, and when dried in the oven, the loss of absorbed water remained constant within 0.1 per cent. This method of retaining surface-dry sand made available test samples of known and quite constant moisture content at all times.

TABLE I.—TEST FOR THE ABSORBED MOISTURE IN THE SAND.

WEIGHT OF DAMP SAND, G.	WEIGHT OF $CaCl_2$ DRIED SAND (24 HOURS), G.	WEIGHT OF OVEN-DRIED SAND, G.	SURFACE WATER, PER CENT	ABSORBED WATER, PER CENT
500.0	424.0	419.8	15.2	0.84
500.0	456.4	452.0	8.7	0.88
500.0	473.6	469.1	4.7	0.90
500.0	484.8	480.2	3.0	0.92
500.0	490.5	486.1	2.1	0.86

The sand used for all tests was from the same source and shipment, from the Willamette River at Corvallis, Ore., thus the colloidal and the soluble material remained constant. This sand was chosen as representative of the usual sand used in concrete work and was not a special or prepared sand. A sieve analysis of the sand used in all the tests gave the following results:

	PER CENT
Passing a No. 100 sieve,	1.5
" " " 48 " and retained on a No. 100 sieve	23.2
" " " 28 " " " " " " 48 "	43.3
" " " 14 " " " " " " 28 "	26.3
" " " 8 " " " " " " 14 "	5.4
" " " 4 " " " " " " 8 "	0.3

The specific gravity tests were all started using a saturated solution. These solutions were prepared by warming an excess of salt with the solution and allowing the supersaturated solution to cool. The solutions used for the tests were decanted from this cooled mixture. Some trouble was experienced in retaining a saturated solution, even with an excess of salt present, for the more concentrated liquors would form a sort of blanket over the excess solid and prevent further solution. This necessitated frequent shaking of the stock solutions.

At first, fresh samples of sand and saturated solution were used for each dilution in the specific gravity *versus* dilution tests using sodium chloride. This required considerable solution, sand, and time. Then a sample of sand was added to the saturated solution and successive portions of water were added to the mixture to obtain the desired dilutions. The latter method was found to be as accurate as the first and was thereafter generally used.

METHOD 2.—DRYING TO CONSTANT WEIGHT WITH DENATURED ALCOHOL.

ADDED WATER, PER CENT	WEIGHT OF SAMPLE, G.	WEIGHT AFTER HEATING, G.	TOTAL WATER, PER CENT	SURFACE WATER, PER CENT
1	500.0	490.0	2.0	1.10
2	500.0	485.6	2.8	1.98
3	500.0	480.4	3.9	3.00
4	500.0	476.6	4.7	3.80
5	500.0	470.0	6.0	5.10

METHOD 3.—DISTILLATION METHOD USING A.S.T.M. STILL HEAD (STANDARD METHOD D 95)

ADDED WATER, PER CENT	WATER DRIVEN OFF, CC.	TOTAL WATER PER CENT	SURFACE WATER, PER CENT
1	9.2	1.84	0.94
2	14.6	2.92	2.02
3	19.8	3.96	3.06
4	25.0	5.00	4.10
5	29.0[a]	5.80	4.90

[a] Estimated.

METHOD 4.—DISPLACEMENT METHOD USING A.S.T.M. FLASK (TENTATIVE METHOD C 70-28 T)

ADDED WATER, PER CENT	DISPLACEMENT OF 500 G. SURFACE DRY SAND, CC.	DISPLACEMENT OF 500 G. DAMP SAND, CC.	WATER BY FLASK, PER CENT
1	397.0	398.0	0.98
2	397.0	399.8	1.78
3	397.0	400.0	2.83
4	397.0	401.2	4.25
5	397.0	402.0	5.10

The method of making each type of test was as follows:

Method 1—Drying to Constant Weight in Oven.—A 500-g. sample of damp sand was placed in a pan and heated in the oven for 30 minutes at 105 to 110° C. It was then weighed and the percentage of moisture was calculated on the damp basis.

Method 2—Drying to Constant Weight with Denatured Alcohol.—A 500-g sample of damp sand was placed in a pan, 100 cc. of alcohol poured over the sand and stirred in with a metal rod. The sample was spread in a layer approximately one inch thick and ignited. During the burning, the sample was frequently stirred with the metal rod. If the sand appeared wet after the initial burning, additional alcohol was added and the process repeated. The dried sand was allowed to cool somewhat and then weighed.

Method 3—Distillation Method Using the Still Head (A.S.T.M. Method D 95).—A 500-g. sample of damp sand was placed in a 500-cc. flask and just enough topped gasoline was then placed in the flask to cover the sand about one-half inch. The still head and condenser were placed in position and the sample heated with an electric heater.

METHOD 5.—SPECIFIC GRAVITY *versus* DILUTION OF 500 CC. SATURATED SODIUM CHLORIDE SOLUTION WITH 500 G. SAND

ADDED, WATER, CC.	WATER IN SAND (DRY), PER CENT	WATER IN SAND (WET), PER CENT	SPECIFIC GRAVITY	COLLINS HYDROMETER
0	0	0.00	1.199	0.4
5	1	0.99	1.197	1.0
10	2	1.96	1.195	2.0
15	3	2.91	1.193	2.6
20	4	3.84	1.191	3.5
25	5	4.76	1.189	4.1
30	6	5.68	1.187	5.1
35	7	6.54	1.186	5.7
40	8	7.40	1.184	6.7
45	9	8.26	1.182	8.1
50	10	9.09	1.180	8.5
60	12	10.71	1.178	10.0
70	14	12.27	1.175	11.3
80	16	13.79	1.172	12.8
90	18	15.25	1.168	14.8
100	20	16.66	1.166	16.2

SPECIFIC GRAVITY *versus* DILUTION OF 311.8 CC. SATURATED SODIUM CHLORIDE SOLUTION WITH 500 G. SAND.

ADDED WATER, CC.	WATER IN SAND (DRY), PER CENT	WATER IN SAND (WET), PER CENT	SPECIFIC GRAVITY	COLLINS HYDROMETER
0	0	0.00	1.198	0.4
5	1	0.99	1.195	1.3
10	2	1.96	1.192	2.5
15	3	2.91	1.188	3.5
20	4	3.84	1.186	5.5
25	5	4.76	1.184	6.5
30	6	5.68	1.180	8.3
35	7	6.54	1.178	10.3
40	8	7.40	1.176	11.2
45	9	8.26	1.173	12.0
50	10	9.09	1.171	12.8
60	12	10.73	1.169	14.0
70	14	12.44	1.165	15.2
80	16	13.79	1.161	18.5
90	18	15.26	1.157	22[a]
100	20	16.66	1.153	....

[a] Estimated.

Method 4—Displacement Method Using the Flask (A.S.T.M. Method C 70).—The flask was filled with water to the 200-cc. mark. A 500-g. sample of sand dried over calcium chloride was poured into the flask. The flask was shaken and the displacement read. The operation was then repeated using the same weight of damp sand.

Method 6.—Specific Gravity *versus* Dilution of 500 cc. Saturated Magnesium Sulfate Solution with 500 g. Sand.

Added Water, cc.	Water in Sand (dry), per cent	Water in Sand (Wet), per cent	Specific Gravity
0	0	0.00	1.291
5	1	0.99	1.288
10	2	1.96	1.285
15	3	2.91	1.283
20	4	3.84	1.280
25	5	4.76	1.278
30	6	5.68	1.276
35	7	6.54	1.273
40	8	7.40	1.271
45	9	8.26	1.269
50	10	9.09	1.266
60	12	10.71	1.263
70	14	12.44	1.259
80	16	13.79	1.254
90	18	15.26	1.250
100	20	16.66	1.247

Specific Gravity *versus* Dilution of 311.8 cc. Saturated Magnesium Sulfate Solution with 500 g. Sand.

Added Water, cc.	Water in Sand (dry), per cent	Water in Sand (wet), per cent	Specific Gravity
0	0	0.00	1.291
5	1	0.99	1.286
10	2	1.96	1.282
15	3	2.91	1.277
20	4	3.84	1.273
25	5	4.76	1.270
30	6	5.68	1.266
35	7	6.54	1.262
40	8	7.40	1.258
45	9	8.26	1.255
50	10	9.09	1.253
60	12	10.73	1.247
70	14	12.44	1.241
80	16	13.79	1.236
90	18	15.26	1.230
100	20	16.66	1.225

Methods 5 to 8—Specific Gravity Methods.—Two series were run on the sodium chloride, magnesium sulfate, and zinc chloride solutions.

In the first series, 500 cc. of the saturated stock solution was taken. Its specific gravity, and then the specific gravity with 500 g. of sand added were determined. Water was added to this in 5-cc. portions up to a volume of 50 cc. and then in 10-cc. portions to a total volume of 100 cc. The sample was well

Method 7.—Specific Gravity *versus* Dilution of 311.8 cc. Saturated Calcium Chloride Solution with 500 g. Sand.

Added Water, cc.	Water in Sand (dry), per cent	Water in Sand (wet), per cent	Specific Gravity
0	0	0.00	1.350
5	1	0.99	1.344
10		1.96	1.340
15	3	2.91	1.336
20	4	3.84	1.332
25	5	4.76	1.328
30	6	5.68	1.324
35	7	6.64	1.320
40	8	7.40	1.316
45	9	8.26	1.312
50	10	9.09	1.309

Note.—A concentrated solution of calcium chloride is very susceptible to temperature, both in regard to solubility and to the specific gravity of a given strength solution.

Method 8.—Specific Gravity *versus* Dilution of 500 cc. Saturated Zinc Chloride Solution with 500 g. Sand.

0	0	0.00	1.957
5	1	0.99	1.941
10	2	1.96	1.925
15	3	2.91	1.910
20	4	3.84	1.895
25	5	4.76	1.880
30	6	5.68	1.864
35	7	6.54	1.851
40	8	7.40	1.839
45	9	8.26	1.827
50	10	9.09	1.817

Note.—It was necessary to add 5 cc. of concentrated hydrochloric acid to the zinc chloride solution to prevent hydrolysis. Otherwise the zinc hydroxide formed prevented the specific gravity from reaching equilibrium on the addition of the sand.

Summary for Specific Gravity *versus* Dilution Method for 311.8 cc. Saturated Inorganic Salt Solutions with 500 g. Sand.

Added Water, cc.	Specific Gravity (NaCl)	Specific Gravity ($MgSO_4$)	Specific Gravity ($CaCl_2$)	Specific Gravity ($ZnCl_2$)
0	1.198	1.291	1.350	1.957
5	1.195	1.285	1.344	1.931
10	1.192	1.282	1.340	1.907
15	1.188	1.277	1.336	1.883
20	1.186	1.273	1.332	1.859
25	1.184	1.270	1.328	1.839
30	1.180	1.266	1.324	1.821
35	1.178	1.262	1.320	1.803
40	1.176	1.258	1.316	1.780
45	1.173	1.255	1.312	1.763
50	1.171	1.253	1.309	1.745
Total difference	0.027	0.038	0.041	0.212
Ratio to NaCl	1	1.41	1.51	7.85

Note.—The values for the zinc chloride were taken from the graph made by plotting the values found in the run using 500 cc. solution.

shaken after each addition, allowed to settle and the specific gravity taken. The surface-dry sand had no apparent effect on the specific gravities of the various solutions.

The second series, which was the one used on the remaining specific gravity determinations, consisted in using 500 g. of sand and 312 cc. of stock solution, that is, in the ratio (1:1.6) used with the Collins Hydrometer and also the ratio used in the experiment described by W. R. Johnson.[1] The method of making the test was the same as in the first series.

Method 9—Colorimetric Methods Using Copper Sulfate.—In the neutral tests, standard solutions of 1 to 10 per cent water content were made by diluting a saturated stock solution. The volumes of these standard solutions were kept at 10 cc. A 500-g. sample of sand was then placed in 500 cc. of a saturated stock solution. The mixture was shaken, allowed to settle, and 10 cc. filtered off. This was then compared with the standard solutions over white glazed paper. This 10-cc. sample was then poured back into the mixture and 5 cc. of water added. This mixture was then well shaken, allowed to settle and a 10-cc. sample filtered off and compared to the standards as before. This operation was repeated until a total of ten 5-cc. portions had been added.

METHOD 9.—COLOR OF COPPER SULFATE SOLUTIONS *versus* PERCENTAGE OF WATER IN SAND.

	ESTIMATED COLOR MATCH OF					
	NEUTRAL SOLUTION		WEAKLY-ACID SOLUTION		STRONGLY ACID SOLUTION	
WATER IN SAND, (DRY), PER CENT	FIRST RUN	SECOND RUN	FIRST RUN	SECOND RUN	FIRST RUN	SECOND RUN
1........	1.2	0.9	0.9	0.9	0.9	0.9
2........	2.1	1.8	1.9	1.9	1.9	2.0
3........	3.0	3.0	2.9	3.0	3.0	3.1
4........	3.5	4.3	4.0	4.0	4.1	4.0
5........	4.6	5.0	4.9	5.0	5.1	5.2
6........	6.0	5.8	6.1	6.2	6.0	5.8
7........	7.2	6.7	7.2	7.1	7.0	7.1
8........	7.5	7.9	7.9	7.9	8.0	8.1
9........	8.7	9.0	8.9	8.8	8.9	9.0
10........	10.1	10.4	10.0	10.0	10.1	10.0

For the weakly-acid solution, 1 per cent sulfuric acid was added to 700 cc. of stock solution and then allowed to set for several hours, to permit any copper sulfate, driven out by the added sulfate ion, to precipitate. From this point on, the procedure was identical to that used for the neutral solution.

For the strongly-acid solution, 10 per cent sulfuric acid was used in place of the 1 per cent. The procedure was identical.

Method 10—Colorimetric Method Using Phenolphthalein in Water.—An alcoholic solution of phenolphthalein from a burette was added to 100 cc. of water until the maximum color was obtained. Water was added to this solution from a burette in 1-cc. portions until 10 cc. was reached. The color change was observed after each addition and was found to be very little. (This was repeated.)

Method 11—Colorimetric Method Using Phenolphthalein in Ethyl Alcohol.—An alcoholic solution of phenolphthalein was added to 100 cc. of ethyl alcohol, containing 1 g. of sodium hydroxide, until maximum color was obtained. Water was then added in 1-cc. portions until 10 cc. was reached. The change in color seemed greater than that of the water solution of phenolphthalein, but it was impossible to detect the difference due to 1-per-cent dilution.

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[1] *Loc. cit.*

Method 12—Electrical Resistance Method.—Two copper electrodes, 10 cm. long and 1 cm. wide, were soldered to copper wires fastened in a rubber stopper. This stopper fitted a liter flask in such a way that the electrodes were covered when 500 cc. of solution was placed in the flask. A mixture of 500 g. of surface-dry sand and 500 cc. of concentrated sodium chloride solution was placed in the flask. A dry cell was placed in parallel with a resistance having a variable tap. One end of the resistance and the tap were placed in parallel with the test cell and a millivoltmeter. This resulted in a variable potential across the cell, which was indicated by the deflection of the millivoltmeter and was in proportion to the resistance of the cell. The resistance tap was then adjusted until a convenient deflection of the millivoltmeter was found, care being taken to have the circuit closed only for the smallest periods of time. The mixture was then removed and a 500-g. sample of damp sand containing 10 per cent moisture was placed in the flask with 500 cc. of the same saturated sodium chloride solution. On closing the switch, the millivoltmeter indicated a drop in resistance in the cell. However, when the sample was allowed to stand

METHOD 12.—CONDUCTIVITY OF SODIUM CHLORIDE SOLUTIONS.[a]

CONCENTRATION IN MILLI-FORMULA WEIGHTS PER LITER (c)	CONDUCTIVITY[b]
1	124.1
2	123.0
5	120.8
10	118.6
20	115.8
50	111.0

[a] International Critical Tables, Vol. VI, p. 233.

[b] Conductivity (25° C.) = $\frac{10^6 k}{c}$; where c = concentration in milli-formula weight per liter; k = specific conductance in ohms^{-1} cm.^{-1}

Conductivity circuit taken from "Practical Physical Chemistry" by Findlay.

METHOD 13.—PEARSON METHOD OF DETERMINING MOISTURE IN SURFACE-DRY SAND.

NOTE.—Sand No. 1 is the sand used in the previous work.
Sand No. 2 is sand No. 1 cleaned.
Point "A" is the point at which the fine sand particles just cease to adhere to the glass.

Value of constant C for flask: 500 g. calcium-chloride-dried sand (24 hours) has a displacement of 397.0 = C.

Absorbed moisture is 0.90 per cent.

WEIGHT OF DRY SAND, G.		WEIGHT OF ADDED WATER, G.	WEIGHT AT POINT "A," G.	FLASK READING, CC.	MOISTURE BY WEIGHT, PER CENT	MOISTURE BY FLASK, PER CENT
Sand No. 1	500	10	504.6	397.5	0.92	0.95
	500	10	504.8	397.5	0.96	0.95
Sand No. 2	500	10	504.4	396.8	0.88	0.88
	500	10	504.4	397.0	0.88	0.90

30 minutes before testing, the difference in resistance of the cell caused a change of only 0.2 to 0.6 millivolts, when the cell was tested after standing several hours, this differences became too small to indicate on the millivoltmeter.

This indicates that the change of conductance of a concentrated salt solution on dilution with sand present is not only small, but that the colloidal material, or some other factor, tends to decrease any drop of resistance resulting from the dilution of the solution. This could be expected from a study of the electrical properties of colloids.

The potential across such a cell as this must be for an instant only and must be less than the decomposition potential of the salt.

Method 13—Pearson Method Using a Mason Jar.—Ten grams of water were added to 500 g. of oven-dried sand in a weighed Mason jar. The jar was then sealed and let set over night. This damp sand was then slowly dried in the jar until the fine particles just ceased to adhere to the sides of the jar on mild shaking. The jar and sand were then weighed and the moisture content of the sand calculated. The sample was then tested in the A.S.T.M. flask (Method C 70) in the usual manner.

DISCUSSION OF TESTS

The drying of the sand over calcium chloride offered an easy means of obtaining a uniform surface-dry sand, and from the tests made, the absorbed water remains constant within the experimental error. The sand may have been more or less than totally surface dry, yet the lack of influence by the calcium-chloride dried sand on the specific gravity of the various solutions indicates that any such moisture in the sand is very firmly held. According to the theory of Helmholtz,[1] there should remain a mono-molecular layer on the surface of the sand particles. This moisture can be regarded as absorbed moisture, for it is more rigidly held than any capillary moisture present. The time for sand to reach equilibrium over calcium chloride offers an objection to drying sand by this method and it is not recommended except to prepare uniform samples.

The oven drives off the moisture in the sand with little trouble. There is still some moisture present, however. This moisture is the mono-molecular layer mentioned above. But such moisture would require a high temperature and a vacuum to remove. The amount of moisture thus held is very small.

Drying the sand by igniting with alcohol does not give the percentage of moisture as accurately as the oven drying method, yet the accuracy of the method is sufficient for work where the total moisture is desired and an oven is not at hand. The discrepancy in the moisture content may be due to driving off solid volatile matter in the sand, ignition of the organic material present, or to removing small particles of solid through the mechanical action of the flame.

The use of a volatile liquid, such as toluene or topped gasoline, and heat to remove the moisture offers the least number of manipulations and chances of mechanical error. The reading of the volume of water driven off can be made about as accurately as desired by changing the shape of the receiver. The apparatus is simple and inexpensive. The method does require weighing, but a simple balance only need be used.

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[1] *Journal*, American Chemical Society, Vol. 40, p. 1361, (1918).

The results obtained from the A.S.T.M. flask (Tentative Method C 70–28 T) are not as accurate as those obtained by the previous methods, the principal trouble being the inability to read the meniscus accurately. The scum formed on the top of the water is a variable, so it is necessary to take the readings at the line of demarcation between the water and scum. This method gives only the surface moisture, and has an accuracy sufficient to permit its use as a control where the absorbed moisture of the incoming sand is constant. But it is not accurate enough for absolute values. It will be noted that the inaccuracy increases somewhat with an increase in the percentage of moisture of the sand. A probable explanation of this is offered by W. R. Johnson in his report.[1] He says that the wet sands collected more scum than the dryer ones, and that the presence of this scum may account for the increased error. The moisture clinging to the scum likely causes some error, but it does not appear sufficient to account for the error found.

The use of a saturated solution of sodium chloride and a hydrometer-type instrument does not give highly accurate results. The inability to read the hydrometer accurately, due to the solution rising on the stem, is the main objection to the method. The slight change of specific gravity of a sodium chloride solution makes it necessary for the hydrometer to have only a small range of specific gravity; hence, this type of instrument is difficult to make accurately and is quite fragile.

The use of calcium chloride offers an increased change in the specific gravity with the percentage of moisture. This would make the hydrometer more accurate. The solubility of calcium chloride changes more rapidly with temperature and is more soluble at all temperatures than sodium chloride. This change of solubility would cause a large error at a varying temperature if the stock solution were kept in contact with excess salt. The change of specific gravity of any constant strength solution does not change any more than that of sodium chloride. Thus the stock solution can be kept at a definite strength and the error due to the differences in temperature would be the same as that of sodium chloride. In short, calcium chloride is more efficient than sodium chloride for specific gravity measurements. The price per pound of calcium chloride is considerably higher than that of common salt. Due to this and to the increased solubility, the calcium chloride method would be quite costly.

The use of magnesium sulfate is a partial compromise between the two. It is not as soluble and is less expensive, but its efficiency is only slightly less than that of calcium chloride. The loss in efficiency would be more than balanced by the greater ease of preparing and keeping a constant specific gravity solution.

A saturated zinc chloride solution has a high change of specific gravity with dilution, and should have a high degree of efficiency. The test indicates that it does have a high efficiency if some hydrochloric acid is present in the solution. This acid prevents, to some extent, the hydrolysis of the zinc chloride. If the zinc chloride is used alone the hydrolysis is too great. The zinc hydroxide formed is less soluble and remains mostly in the colloidal state. The result is a solution of lower specific gravity that may change at any time, for the precipitation of the colloidal hydroxide will cause the hydrolysis to continue. The main objection to the use of zinc chloride lies in the fact that it will burn the skin. This burn is slow to heal and is painful.

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[1] *Loc. cit.*

The accuracy of the specific gravity determination depends to a large degree on the means of measurement. If the Westphal balance is used the accuracy is several times that of a usual hydrometer.

Colorimetric methods seem to offer little hope. The change of color is enough to warrant their use, but the selective absorption by the colloidal material seems to influence the amount of coloring material present in a test sample. The sand particles may help in absorbing some of the coloring material, but the colloidal material present is probably the main factor. The use of some dye in place of a colored inorganic salt might be worth investigating.

The electrical resistance of a solution with sand present does not appear to be valuable as an indication of the water present. A change in concentration of 1 per cent salt is almost too small to be accurately measured with a pure solution and the best of apparatus. From this, the change found on the slight dilution made by the water in the sand would be extremely hard to measure, even if the sand contained no impurity. Colloidal particles have an electrical charge, and may reverse their charge under certain conditions. The charge is variable in intensity, depending on the size of the particle and the method of forming the colloid. Any charged particles in an ionized solution have a large effect on the ionization and thus on the conductivity of the solution. Since the charge on the particles may vary, the effect on the ions would vary, and the resistance would change.

From the small change of resistance with dilution and the effect of the colloidal matter present, the use of resistance measurements becomes of no value.

In the report by W. R. Johnson previously referred to, he reports on the use of an electrical resistance meter that depends on the resistance of the damp sand. He says, " . . . the apparatus was made for testing the relative moisture content of foundry sands, but was found to be not well suited for the coarser sands used in concrete construction. . . the results were not accurate."

The shaking of sand in a glass jar, to determine whether the sand is surface dry or not, is almost as accurate as the A.S.T.M flask. Care must be taken in determining the point at which the particles just cease to adhere to the glass. The violence of shaking must be controlled and the drying must be slow. The presence of dirt or dust in the sand will tend to cause serious errors in the determination. If the sand is comparatively clean, this method of defining surface dry sand can be considered accurate enough for general use in concrete construction.

CONCLUSIONS

For total moisture, the oven-drying method is the most accurate, the distillation method second, and the alcohol method third. In simplicity of operation the distillation method is first, the oven drying method second, and the alcohol method third. In regard to the amount of apparatus needed the alcohol method is first, the oven drying method and the distillation method are about equal.

To determine the surface moisture only, the specific gravity methods using zinc chloride, magnesium sulfate, calcium chloride, and sodium chloride rank in accuracy in the order named. The A.S.T.M. flask is more accurate than the specific gravity method using sodium chloride. The colorimetric methods using a weak acid solution of copper sulfate are more accurate than the electrical method, but not accurate enough, at least for general use.

In simplicity the specific gravity and the A.S.T.M. flask methods are about equal. They require almost identical manipulations and differ only in the apparatus used.

For the determination of the total moisture the distillation method seems the most convenient and is almost as accurate as the oven drying method. The alcohol method is adaptable to use where the apparatus necessary for the distillation or oven method is not available.

To determine the point at which sand is surface dry, the Pearson glass jar method is the most simple and has an efficiency entirely satisfactory for control work.

The tests appear to favor the A.S.T.M. flask. It is simple in construction and manipulation. The time required for a determination is not great. The flask has, in comparison to the other methods tried, a satisfactory degree of accuracy, according to these tests, and this work, therefore, confirms the use of the A.S.T.M. flask as a suitable standard for the determination of moisture in sands.

APPENDIX VIII

APPARATUS FOR FLEXURAL TESTS OF CONCRETE BEAMS

By A. T. Goldbeck[1]

In view of the wide use of flexure tests for concrete, especially for concrete highway construction, a thorough investigation of flexure testing is desirable. A number of different types of flexure test machines have been used and considerable variation in results has been found, due to variables in the dimensions of the test specimen, the type of loading and the type of testing machine. In the present report, some theoretical defects in flexure testing machine design are discussed.

Discussion of the Flexure Test

It is assumed that the bending stresses produced in the flexure test vary directly as their distances from the neutral axis of the beam, that is, in accordance with a straight-line law of variation and that compressive stresses are produced on one side and tensile stresses on the opposite side of the neutral axis, both of like intensity.

The results of the flexure test are expressed in terms of the so-called modulus of rupture which is calculated by the general flexural strength formula, as follows:

$$R = \frac{Mc}{I}$$

where R = the flexural strength;
M = the bending moment at the section of failure;
c = the distance from the neutral plane to the most remote fiber or one-half the depth of a rectangular cross-section;
I = the moment of inertia ot the cross-section.

The use of the flexure formula for calculating the modulus of rupture involves the extension of the scope of this formula to limits beyond which it does not theoretically apply. According to its derivation the formula applies only within the proportional limit of the material but nevertheless it is used for calculating the extreme fiber stress at failure (the modulus of rupture). Obviously, this stress exceeds the proportional limit. However, because concrete in a bending test fails on the tension side at a comparatively low tensile stress and, moreover, since the stress-strain relation is almost a straight line for low values of stress, the error introduced through the liberties which are taken with this application of the formula is probably not appreciable.

Types of Machines Used and Their Possible Effects

Various schemes of loading are represented in Fig. 1 and in connection with each of these types are shown the shear and bending moment or stress diagrams. The loading shown in Fig. 1 (*a*) will be obtained with the type of machine represented in Fig. 2 (*f*) that in Fig. 1 (*b*) by the machine represented in Fig. 2 (*d*). That in Fig. 1 (*c*) is a simple beam with a single load applied at the center and with appropriate bearing blocks for permitting of free horizontal motion at the ends of the beam. Figure 1 (*d*) is a simple beam with third-point loading, the loads and reactions, however, being vertical forces only.

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[1] Director, Bureau of Engineering, National Crushed Stone Assn., Washington, D. C.

From the standpoint of character of stresses produced there seems to be little to choose between the types of loading shown in (*a*), (*b*) and (*c*) of Fig. 1. The shear diagrams and the bending moment diagrams of each are almost identical. It is true that in type (*a*) there is a very small distance at the center over which there is zero shear but in the method of loading ordinarily used this distance is so small as to be practically negligible. In Fig. 1 (*d*) there is a zone at the center equal to one-third of the span length over which there is zero shear and constant bending stress. In Figs. 1 (*a*), (*b*) and (*c*), should the specimen fail at some point other than at the center, it is necessary to measure the location of the break in order to calculate the bending moment at the section of failure. This same statement applies to the type loading shown in Fig. 1 (*d*), should the break occur in the outer third of the beam. Should the break occur in the middle third, however, no measurement need be made because the bending moment is constant. In the case of types (*a*), (*b*) and (*c*) of Fig. 1, theoretically, there is just one section where failure should take place, namely, at the point of maximum bending moment. In type (*d*), Fig. 1 there are an infinite number of sections throughout the middle third of the beam at which failure may take place because of the equal stress produced throughout the middle third.

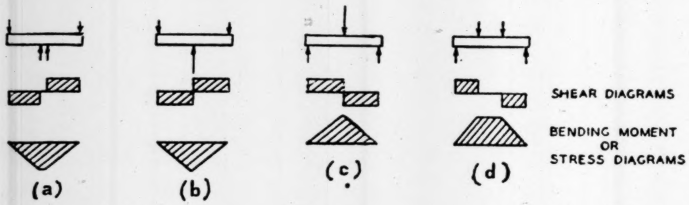

FIG. 1.—Shear and Bending Moment Diagrams for Various Types of Loading.

The fact that maximum bending moment takes place in just one section in types (*a*), (*b*) and (*c*) of Fig. 1, results in the possibility that the test may not be truly indicative of the modulus of rupture of the concrete should there be any great variation in the modulus of rupture throughout the length of the beam. On the other hand, the method of third-point loading as shown in Fig. 1 (*d*) is much more likely to produce failure at the weakest section of the concrete should this section occur within the middle third of the beam. It should be expected, therefore, that the method of loading at the middle third would give somewhat lower results for modulus of rupture than those methods which produce maximum bending moment at a single section.

There are practical considerations to be taken into account in connection with the type of loading used. These may be listed as follows. A third-point loading method requires a higher total load than a single point loading and for a given length of beam the testing machine would have to be of larger capacity. Also more equipment is necessary to produce two-point loading than single point loading. The vertical shear in a beam is likewise greater in the end

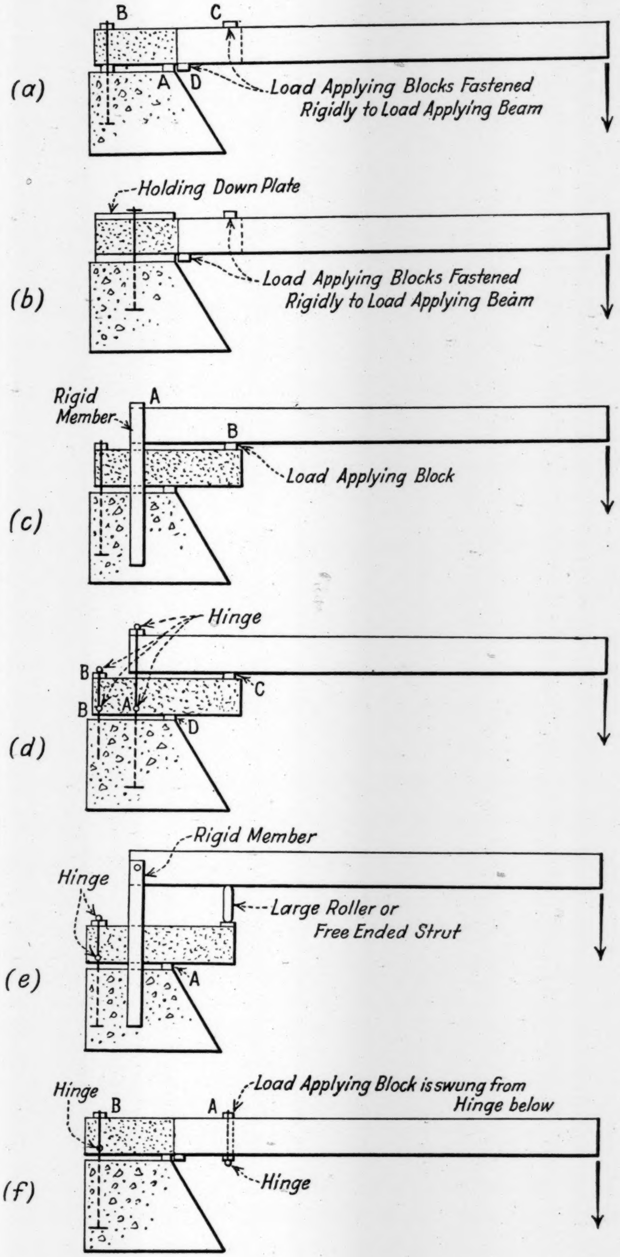
(a)
B
C
A
D
Load Applying Blocks Fastened Rigidly to Load Applying Beam
(b)
Holding Down Plate
Load Applying Blocks Fastened Rigidly to Load Applying Beam
(c)
Rigid Member
A
B
Load Applying Block
(d)
Hinge
B
B
A
C
D
(e)
Rigid Member
Hinge
Large Roller or Free Ended Strut
A
(f)
Hinge
B
A
Load Applying Block is swung from Hinge below
Hinge

FIG. 2.—Diagrams of Six Different Types of Apparatus for Flexural Tests of Concrete Beams.

thirds than in the case of the single loading, and since for practical considerations, the beam has to be short, the combination of vertical shear and horizontal stress may result in the production of principal tensile stresses of high value. The span length of a beam for two-point loading would have to be greater than for single point loading or for cantilever loading in order to get as many breaks per beam. This, of course, is somewhat undesirable because of the increased amount of material required and the inconvenience in handling the specimens.

In Case I, Fig. 2 (*a*), the specimen is tested as a cantilever beam. It rests upon a support at point *A* and is held down to that same support by means of a clamp applied at point *B*. Load is applied by hanging an auxiliary beam at the end of the specimen. This beam is loaded at its outermost end and downward force on the specimen thus results at point *C* and upward force at point *D*. In this machine the load-applying blocks *C* and *D* are rigidly fastened to the load applying beam.

Let it be assumed that the horizontal distance from *D* to *C* is 10 in. Assume the stress in the concrete to equal 600 lb. per sq. in. at the dangerous section. The upper fiber in the concrete beam will then elongate an amount due to an average stress of 300 lb. per sq. in. This elongation equals:

$$300 \times \frac{10}{3{,}000{,}000} = 0.001 \text{ in.}$$

Let us assume that the load-applying beam is made of wood and that it is so designed that a unit fiber stress of 1000 lb. per sq. in. is produced in the wood at the dangerous section at the same time that 600 lb. per sq. in. is produced in the concrete. The average stress in the wood in the upper fiber of the load-applying beam extending from *C* to *D* then equals 500 lb. per sq. in. and the elongation equals:

$$500 \times \frac{10}{1{,}500{,}000} = 0.0033 \text{ in.}$$

It is thus seen that the fibers of the wood have stretched $0.0033 - 0.001$ or 0.0023 in. more than the concrete. Consequently, there will be a tendency for the load-applying block *C* to slide outward toward the end of the concrete beam and a horizontal force due to friction will be produced. In calculating the value for modulus of rupture it is assumed that the only stress which is produced in the concrete is that due to the bending effect of vertically applied force but in this type of testing machine, unconsciously, we have applied horizontal force as well as vertical force at points *C* and *D*. The bending moment at the dangerous section is taken as equal to the vertical load applied at the end of the load-applying beam multiplied by its lever arm but this neglects the moment of the horizontal force introduced at the end of the beam through the effect of deformation. It would seem well to avoid the creation of unknown horizontal forces whose stress effects are uncertain.

Still another variation in the cantilever type of machine as above described is that shown in Fig. 2 (*b*). In this case the beam is clamped down rigidly to its support by means ot a cover plate which theroetically does not affect the fiber stress at the dangerous section as compared with Fig. 1 (*a*), since the bending moment is identical in both cases. However, it would seem that with this method of support for the specimen and with this method of clamping, uncertain stresses are induced due to the clamping action. It is certain that there can be a wide variation in the vertical forces acting on a beam at the supports due to this method of holding the beam in position, and because it is impossible to tell when conditions are being duplicated, this method of clamping the beam in position is to be avoided.

In Case II the load is applied to the beam by an auxiliary beam as shown in Fig. 2 (*c*). In this particular design the end of the load-applying beam is tied down to the support with a rigid member which does not permit of horizontal motion of point *A* with respect to the support. Bearing block *B* rests upon the concrete specimen and vertical load is applied at the end of the load-applying beam. As the upper fiber of the concrete stretches under load, point *B* at the top of the concrete beam will tend to move to the right. Point *B* on the under side of the load-applying beam, on the other hand, will tend to move to the left because the lower side of the load-applying beam in this case is in compression and point *A* is rigidly fixed. Therefore, the elastic movement of the entire system under load tends to create relative motion between the end of the concrete specimen and the point immediately above it in the load-applying beam. The tension produced by bending is thereby decreased and this type of machine gives high results for modulus of rupture. No doubt it would be possible to arrive at a fair estimate of the error occurring under this condition of loading, provided the exact details of the machine were known. This, however, is unimportant. The important point is that a machine of this design gives uncertain results.

The machine shown in Fig. 2 (*d*), Case III, is a modification of that in Case II. Here, the member *A* holding down the load-applying beam is not a rigid member as in Case II, but is hinged at A-A. Moreover, the member holding down the concrete specimen is also hinged at B-B. The fact that the holding-down member A-A is hinged, means that the force of the load-applying beam at *A* must be a vertical force, it cannot act in any other direction than *A-A*. The load is applied as shown by the arrow leading in a vertical direction, and therefore, the load at the end of the concrete specimen must, of necessity, be vertical. The reaction at block *B* must be vertical because of the hinges at *B-B*. It follows that the reaction at *C* must also be vertical and the concrete specimen is acted upon only by vertical loads and the stress produced is bending stress due to vertical forces alone. The material of which the load-applying beam is made plays no part whatever in influencing the stress in the concrete specimen as has been shown to be so in Case I, Fig. 2 (*a*) and (*b*). Modification of the machine in Fig. 2 (*d*) may be made by making use of so-called flexure members at *A-A* and *B-B* instead of using hinges. Such members will bend laterally when load is applied and will thereby offer practically no resistance to horizontal movement of the end of the beam and therefore will not influence the stress or the modulus of rupture of the concrete.

Still another design, which should accomplish the same purpose as Case III, is illustrated in Fig. 2 (*e*). In this case a large roller is used at the end of the beam so that the load applied at this point must be essentially vertical, notwithstanding the fact that the inner end of the load-applying beam is fastened by means of a rigid support. In some machines, very small rollers, only $\frac{1}{4}$ in. in diameter, have been employed in the type shown in Fig. 1 (*e*), in place of the single large roller to insure that the load applied at the end of the concrete specimen is vertical. With this method there is still the chance of error due to the possibility of high rolling friction of the small rollers. It will be safer to avoid the use of small rollers. There are a number of other variations in machine design which could be discussed but perhaps enough has been said to emphasize the fact that extreme care must be used to see that no machine is employed for beam testing which applies horizontal components of force as well as vertical components due to the elastic deformation of machine or specimen, or both.

MODIFICATION OF EXISTING MACHINES

To insure vertical reactions and loads, it is quite possible to modify some of the machines now being largely used and which are giving uncertain results. For instance, Case I, Fig. 2 (*a*) may be very simply modified as shown in Fig. 2 (*f*). This modification consists in the use of a hanger for the load-applying block *A* and for the reaction block *B*. In this case, instead of attaching block *A* rigidly to the edge of the load-applying beam, it is swung from a hanger which is hinged at the lower side of the load-applying beams. Similarly, instead of bolting load-applying block *B* rigidly to the specimen, it is swung at the end of a hanger hinged at its lower end near the support. With this arrangement, all of the forces acting on the specimen remain vertical forces as the load is applied and the modulus of rupture is therefore uninfluenced by unknown horizontal forces as in Case I, Fig. 2 (*a*).

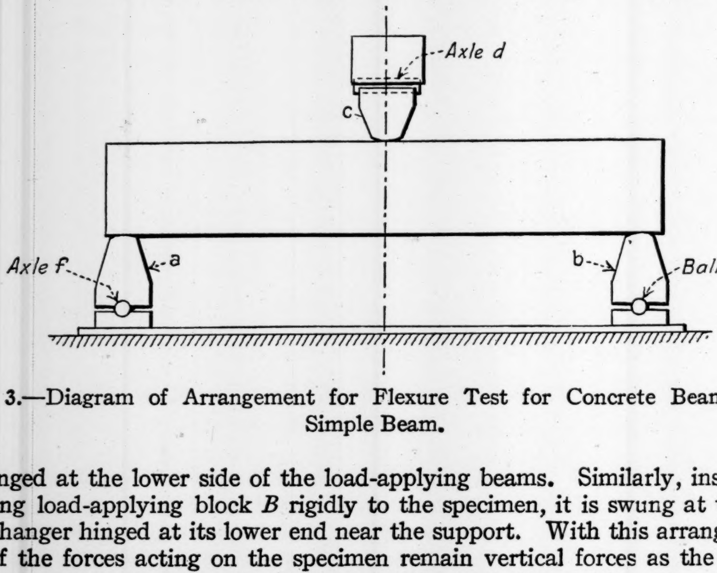

FIG. 3.—Diagram of Arrangement for Flexure Test for Concrete Beams as a Simple Beam.

Case II, Fig. 2 (*c*), as has already been indicated, may be modified to give correct results as shown in Case III, Fig. 2 (*d*).

It should go without saying that in addition to eliminating the above defects, every effort should be made to insure axial loading and also to eliminate any possibility of eccentric loading at the reaction points and at the points of load application.

SUGGESTED DESIGN FOR TESTING SIMPLE BEAMS WITH SINGLE LOAD AT CENTER

Accompanying the present report of Committee C-9 is a suggested design of bearing blocks for testing beams as simple beams subjected to a single load at the center. Diagrammatically this set-up is illustrated in Fig. 3. It is arranged so that the top bearing block *a* can move longitudinally and laterally. Block *b* can move longitudinally only, while block *c* can move only laterally. Theoretically, as load is applied, and the lower fibers of the specimen elongate, the tops of blocks *a* and *b* should move outward equal amounts. The lateral motion of blocks *a* and *c* provides automatic adjustment to take care of lack of parallelism of the transverse elements of the top and bottom surfaces of the beam.

CONCLUSION

In conclusion, it is well to state that some of the considerations above cited are theoretical and they may be found to have no practical application because their effects are small as compared with variations unavoidable in the manufacture of the test specimens. Thus, it may well be that when matters of convenience are considered in conjunction with questions of theoretical exactness, it will be expedient to adopt the most convenient scheme of testing which gives the practical degree of accuracy required.

APPENDIX IX

BIBLIOGRAPHY ON MIXING CONCRETE[1]

1818

(1) "Treatise on Mortars and Cements," by L. J. Vicat, 1818, Translation from French by J. T. Smith, 1837, p. 79.

There is not the least danger in beating up fresh mortar which has begun to harden, and bringing it back to its first consistency by the addition of water, provided this hardness was brought on in a few hours by heat of sun or scorching wind.

1865

(2) "Experiments on Strength of Cement," by J. Grant, *Proceedings*, Inst. Civil Eng., 1865–1866 and 1870–1871. Reprinted in book form by Spon, 1875, pp. 103, 149.

Remixing mortar made of Rosendale cement every day for 20 days was found to increase strength materially, maximum strength being obtained at 10 days. Regaging not recommended, as later results may not prove favorable.

1870

(3) "Limes, Hydraulic Cements and Mortars," by Q. A. Gillmore, p. 303, Van Nostrand, N. Y., 1870.

Approves of letting fat lime and pouzzoulana remain mixed for some time before tempering them just prior to use.

1885

(4) "Briquets Retempered After Pulverizing," by E. Clarke, *Transactions*, Am. Soc. Civil Engrs., Vol. 14, p. 169 (1885).

Tensile strengths of retempered concrete tabulated.

1886

(5) "Plastic Concrete," by W. R. Kinipple, *Proceedings*, Inst. Civil Eng., Vol. 87, p. 66 (1886).

Tests on retempered concrete.

1888

(6) "Experiments on Regauged Mortar," by H. Faija, Soc. of Engrs. (London), 1888.

Rests results given.

1893

(7) "Investigation on Effect of Retempering upon Strength of Cement Mortars," by Goddard and Evans, *Engineering News*, Vol. 29, January 5, 1893, p. 16.

Tests with 4 portland and 2 Rosendale cements indicate that all cements lose strength by resetting. Rosendale was affected more than portland; former appeared to regain strength at faster ratio than latter. Retempering not recommended.

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[1] This bibliography was prepared by the Portland Cement Assn., and except as indicated the abstracts have been prepared by members of the Portland Cement Assn. staff.

1894

(9) "Notes on Hardening of Mortar," by W. P. Mason, *Journal*, Am. Chemical Soc., Vol. 16, p. 733 (1894).

Extract from thesis of J. A. McPherson, Rensselaer Polytechnic Institute. Retempering tests from 3 to 7 days after mixing indicate that lime mortars slowly gain in strength by retempering in proportion to number of days after mixing. Tests made tempering mortar in water containing sugar, and in bullock's blood. Former given practically no variation from mortar tempered in pure water, but latter gains about 10 per cent in tensile strength.

(10) "Regaging Cement Mortar, Cohesion and Adhesion," by E. S. Wheeler, Report, Chief of Engr., U. S. A., 1894, p. 2327; 1895, p. 2979.

Test results tabulated.

1898

(11) "Cements and Hydraulic Limes," by E. Candlot, p. 355.

Mortars regaged after 12 and 24 hours, while showing great loss in strength at 7 and 28 days, gave only small loss on long-time tests.

1901

(12) "Cements Held in Mixing Bed Different Periods Before Setting Undisturbed," *Tests of Metals*, Watertown Arsenal, p. 343, 1901, 1904; *Minutes*, Assn. Am. Portland Cement Mfrs., April, 1905, p. 7; *Cement Age*, Vol. 2, June, 1905, p. 25.

Compression tests on concrete from same batch at 2-hour intervals up to 2½ days. Several domestic portlands, German portland and natural cement used. Portland cements maintain their strengths several hours after gaging. Strengths at various periods given.

1902

(13) "Recent Experiments with Cements, Mortar and Concrete," by T. S. Clark, *Engineering News*, Vol. 48, July 24, 1902, p. 67.

Tables of test results with tempered and untempered Rosendale and portland cements. The quicker-setting (Rosendale) more seriously affected by retempering. Retempering should not be permitted.

(14) "Retarding Setting of Cement by Continuous Mixing After Wetting," by G. Y. Skools, *Engineering News*, Vol. 48, November 6, 1902, p. 382.

Tensile strengths of cements and mortars with various times of mixing to determine how long concrete can be kept alive.

1903

(15) "Materials of Construction," by J. B. Johnson, p. 593, John Wiley and Sons N. Y., 1903.

Tests from various authorities described.

(16) "Mortar Experiments," by T. F. Richardson, Report, Metropolitan Water and Sewerage Board, 1902, p. 93; 1903, p. 120.

(17) "Efficiency of Concrete Mixing Machines," by Clarence Coleman, *Engineering News*, Vol. 50, August 27, 1903, p. 186.

Requirement is for thorough mixing with amount of water under perfect control and in minimum length of time. Tests on hand mixing of 1:3 cement mortar with mixing time varied from 1 to 10 minutes show maximum strength for 8 minutes mixing. Amount of mixing water practically constant up to and including 6 minutes mixing. Then water was increased slightly for longer mixing periods.

Classification of Mixing Machines

A. Batch Mixers:

Class 1.—Revolving drum fitted with deflectors inside and capable of receiving or discharging a batch while rotating.

Class 2.—Revolving drum formed by two cones with bases joined together having deflectors inside.

Class 3.—A revolving circular pan having a frame with radial arms carrying plows which are lowered into the pan for mixing.

Class 4.—A horizontal revolving cylinder mounted on wagon wheels. Stops to receive materials and to discharge concrete. Cylinder is revolved by gearing from axle.

Class 5.—Horizontal trough of semi-cylindrical cross-section with a longitudinal shaft carrying blades. Blades are set at angle to mix material and feed mixture toward discharge end.

Class 6.—Cubical box revolving about horizontal axis passing through two diagonally opposite corners of box.

Class 7.—A cubical box revolving about horizontal axis as in No. 6, but having corners cut away so machine can receive and discharge a batch without stopping.

B. Continuous Mixers:

Class 8.—An inclined chute fitted with pins. Materials thrown in at upper end and slide by gravity being mixed by deflections caused by pins.

Class 9.—A series of funnels placed one above the other and having in the wide mouth of each funnel an inverted cone forming a baffle. The upper funnel has a bottom door to retain the batch of aggregates.

Class 10.—A long inclined box revolving on its longitudinal central axis. Materials are fed in at upper end.

Class 11.—Same as Class 10 except box is cylindrical in shape and is fitted inside with deflectors.

Class 12.—An open trough or closed cylinder with a shaft on which blades or paddles are mounted to mix and feed to discharge end.

Comparison of Concrete Mixers

Class 1.—Requires that water be introduced first to distribute cement and is a doubtful practice. Claim is made that part of batch on which cement falls when putting batch in mixer will be richer in cement than balance of batch.

Class 2.—Has same objection as Class 1 to lesser degree.

Class 3.—Success of this type depends on equal distribution of cement over aggregates in pan.

Class 4.—Same objections as Class 1 and 2 only more marked.

Class 5.—No mixing parallel to axis of revolution of paddles.

Class 6.—Claim excellent mixing action. Concrete thrown from one side of cube to another six times in one revolution.

Class 7.—Same as Class 6 but advantage of having concrete visible and not stopping to charge or discharge.

Class 8.—Continuous mixers can not mix well or produce uniform concrete.

RATINGS OF ABOVE MACHINES FOR EFFICIENCY OF MIXING

BATCH MIXERS	EFFICIENCY, PER CENT	CONTINUOUS MIXERS	EFFICIENCY, PER CENT
Class 1	75	Class 8	30
" 2	85	" 9	27
" 3	86	" 10	46
" 4	44	" 11	46
" 5	70	" 12	63
" 6	75		
" 7	99		

(A. A. LEVISON.)

1905

(18) "Retempering," by P. L. Wormeley, Jr., *Farmers Bulletin 235*, U. S. Bureau of Public Roads, 1905, pp. 13 and 31.

Concrete suffers little loss of strength if thoroughly mixed with sufficient water to restore normal consistency. Table of test results.

(19) "Concrete and Concrete-Steel in United States—Retempering," by E. Thatcher, *Cement Age*, Vol. 1, January, 1905, p. 330.

Mentions Clark and Skeels' Tests and explains Kinipple system of placing concrete under water, which consists of allowing concrete to partially set before placing, so that cement will not separate when thrown into water.

1906

(20) "Retempered Mortar in Concrete Work," by E. McCullough, *Engineering News*, Vol. 55, January 11, 1906, p. 30; Abstract, *Cement Age*, Vol. 2, p. 678.

Tells of experiences of old English mason with retempered concrete for repairing and bonding old concrete with new. Mason's explanation for action given. Author concludes that retempered mortar with a little lime is good for repairing concrete and also bonding new and old material.

(21) "Tempering Mortar," by J. H. Granberg, *Engineering and Mining Journal*, Vol. 81, January 13, 1906, p. 88.

Mentions tests of C. W. Smith on tempered concrete. Suggests that concrete made of portland cement be placed before setting. Lime mortars can stand longer than cement mortars, as it is harmed to a lesser degree. For finishing walls, lime mortars should be allowed to stand for 10 days or more.

(22) "Tests of Tempering of Mortar," *Cement Age*, Vol. 3, p. 200 (1906).

1907

(23) "Cement and Concrete," by L. C. Sabin, pp. 251 and 259, McGraw Hill Book Co., N. Y., 1907.

Tabulates test results. Adhesive strength of mortars diminished by regaging. Regaged mortars give good results in sea water.

(24) "Concrete and Reinforced Concrete Construction," by H. A. Reid, p. 133, Clark, N. Y., 1907.

Tests with German and domestic portland and natural cements. Domestic had practically same strength 8 hours after being gaged as it had originally; German cement lost 25 per cent at this period.

(25) "Process of Preserving Completely Prepared Cement Mortar Without Loss of Its Property of Setting," by J. H. Magens, French Patent No. 373,834, January 23, 1907; *Journal*, Soc. Chemical Ind., Vol. 26, July 15, 1907, p. 762.

Mortar cooled at time of manufacture below temperature of air and kept in movement or shaking until used, in order to retard setting.

(26) Value of Thorough Mixing of Concrete, Table 152, "Cement and Concrete," 1907 Edition, by L. C. Sabin.

Experiments on hand-mixed concrete.

	MODULUS OF RUPTURE OF BEAMS, LB. PER SQ. IN.	
AMOUNT OF MIXING	48-IN. SPAN	20-IN. SPAN
Turned once and back	290	373
" twice and back	294	353
" 3 times and back	306	444
" 4 times and back	328	474

(A. A. LEVISON.)

1908

(27) "Effect of Time of Mixing with Patented Huser Mixer," *Beton und Eisen*, p. 302 (1908); *Armierter Beton*, p. 199 (1914).

(28) "Proportions of Concrete and Methods of Mixing," by L. C. Wason, *Engineering Record*, Vol. 57, February 15, 1908, p. 194.

(29) "Comparative Costs of Mixing Concrete by Hand and by Machine and Miscellaneous Data on Concrete and Mortar," by Clarence Mayer, *Engineering and Contracting*, Vol. 29, No. 16, April 15, 1908, p. 221.

Comparison of hand and machine mixing. Data given in tables.

Machine mixing on 1445 cu. yd. cost 34 cents per cu. yd. for labor, with 15 minutes required to produce a yard of concrete.

Hand mixing on 1481 cu. yd. cost 53 cents per cu. yd. for labor, with 29 minutes required to produce a yard of concrete. (A. A. LEVISON.)

1909

(30) "Influence of Delay in Application of Cement Mortar," by H. Urbach, *Cement und Beton*, June, 1909, p. 392.

Tables show test results with retempered mortars at various periods after gaging

(31) "Influence of Storing Gauged Cement Mortar," by H. Burchartz, *Mitteilungen*, Kgl. Materialprüfung, Vol. 4, (1908); *Cement Age*, Vol. 9, July, 1909.

Strength test results at Gross Lichterfelde; storing up to 8 hours does not materially affect strength of slow-setting mortars.

(32) "Bonding of Layers of Mortar After Different Time Intervals," by B. Kirsch, *Proceedings*, Internat. Assn. Testing Mats., No. XIII (1909).

(33) "A Method of Mixing Concrete by Hand," *Engineering and Contracting*, March 31, 1909, pp. 31, 13, 237.

Mixing board; runs; tools and plant, runs; mixing; mixing natural mixture of bank sand and gravel. Table giving quantities of material to cubic foot.

1910

(34) "Cost of Mixing and Placing Concrete by Hand, Placing in a Four-Foot Circular Sewer," *Engineering and Contracting*, Vol. 24, No. 2, July 13, 1910, p. 29.

Work on a 4-ft. sewer in Louisville, Ky., carried on entirely by hand. The invert contained 0.21 cu. yd. of concrete and the arch 0.18 cu. yd. per lineal foot, each built separately. Cost of laying 72 ft. of invert or arch $12.19. Gives for 72 ft. of complete sewer a cost of 87 cents per cu. yd. In this work there were about 2.23 lb. of steel reinforcement per lineal foot of sewer. (A. A. LEVISON.)

(35) "Cost of Mixing and Placing Concrete by Hand at Riverside, Calif.," *Engineering and Contracting*, Vol. 34, No. 20, November 16, 1910, p. 424.

Concrete was mixed and placed by hand in 6 in. wall with experienced labor during 1909, cost $1.19 per cu. yd. An itemized account of cost of work is given by C. W. Gaylord in *Cement and Engineering News*. (A. A. LEVISON.)

1911

(36) "Concrete Methods in Rochester," *Municipal Journal*, June 7, 1911.

Experiments showing strength increase and deformation decrease by retempering.

(37) "Retempered Mortar as Bonding Material," by J. F. Skinner, *Municipal Journal*, May 31, 1911. *Cement Age*, Vol. 13, September, 1911, p. 97.

Recommends slush coat of retempered concrete on old concrete before new concrete is poured as expansion due to sudden rise in temperature and decrease in volume due to loss of heat in initial setting is eliminated and thus there is no tendency for new and old concrete to shear along joint.

(38) "Effect of Regaging Mortar," by H. Burchartz, *Mitteilungen*, Kgl. Materialprüfung, Vol. 29, p. 164 (1911); *Journal*, Soc. Chemical Ind., Vol. 30, p. 687; (1911).

Diagram and tables to show decrease in strength in proportion to time which elapses between gaging and regaging.

(39) "Transported Concrete," by H. Burchartz, *Beton und Eisen*, July 1, 1911.

1912

(40) "Consistency, and Time in Mixing Concrete," by H. F. Porter, *Cement and Engineering News*, Vol. 24, August, 1912, p. 236; *Cement Age*, Vol. 14, June, 1912, p. 294.

1913

(41) "Should Concrete be Mixed Longer than is Now Common?" (Editorial), *Engineering News,* Vol. 70, December 4, 1913, p. 1139.

(42) "Retempered Mortar as Finishing Coat for Concrete Surfaces," by J. B. Hawley, *Engineering News,* Vol. 69, April 3, 1913, p. 689.

Method of retempering and applying mortar.

(43) "Retempered Mortar as Bond Between Old and New Concrete," by A. A. Northrop, *Engineering News,* Vol. 70, July 24, 1913, p. 178, August 7, 1913, p. 274.

Practice in British Isles to use small amount of retempered mortar in setting of tile in wall. This prevents cracking, as mortar holds its shape. Method of mixing described.

(44) N. J. Ampere, Lock-Joint Pipe Co., *Engineering News,* Vol. 70, December 4, 1913, p. 23.

Pressure tests of jointed concrete pipes. Persistive qualities of pipes under severe pressure conditions. No waterproofing of any sort used in any of pipe. Opinion that superior watertight quality of concrete is due to richness of mixture and carefulness of mixing.

Possible to produce impervious concrete by proper proportioning. Thorough mixing and introduction of mixture into forms without segregation essential. Pipe tested to 200 lb. per sq. in. with no leakage. (A. A. LEVISON.)

1914

(45) "Time Required for Machine-Mixed Concrete," discussion, by Kinney, Bennett, Wason and Howes, *Concrete-Cement Age,* Vol. 5, October, 1914, p. 162.

(46) "Influence of Time of Rotation in Mixing Machines on Strength of Concrete," by G. Mahir, *Beton und Eisen,* No. 19, p. 414, (1914); *Chemical Abstracts,* p. 564 (1914).

Used various mixing machines and also hand-mixing. Homogeneous mixture not possible under 3 minutes of machine mixing; hand mixing satisfactory but entails greater cost. (A. A. LEVISON.)

(47) "Industrial Railway for Conveying Materials in Concrete Road Construction," *Concrete and Cement Age,* Vol. 5, September, 1914, p. 3.

The 1914 specifications for Wayne County require that batch shall be mixed 1 minute and mixer drum shall revolve 16 times per batch.

Tests made of batches mixed with from 8 to 32 revolutions and it was found that 16 revolutions gave concrete of the greatest strength in the shortest time. (A. A. LEVISON.)

1915

(48) "Microscope Shows Importance of Mixing as Factor in Making Strong Concrete," by N. C. Johnson, *Engineering Record,* Vol. 71, March 6, 1915, p. 301.

(49) "Materials *versus* Methods," by N. C. Johnson, *Engineering Record*, Vol. 72, December 4, 1915, p. 684.

Testimony of moving pictures in study of concrete. Part I on mixing suggests necessary function of concrete mixer and points out evils of short mixing period.

(50) "Strength of Concrete as Influenced by Duration of Mixing," by H. H. Scofield, *Proceedings*, Indiana Eng. Soc., Vol. 35, p. 268, (1915).

(51) "Central Plant for Concreting Over Large Area," by F. L. Shea, *Engineering News*, Vol. 74, September 2, 1915, p. 458.

(52) "Gasoline Dinkeys Haul Concrete," *Engineering News*, Vol. 74, December 2, 1915, p. 1085.

Central mixing plants for hauls up to three-quarters mile without segregation on Chesapeake and Ohio Northern Ry., Greater Winnipeg Water Supply, and Harrisburg, Pa., Bridge of Cumberland Ry.

(53) "Mixer Supplies Three Jobs; Gasoline Dinkey Haulage," by H. B. Watters, *Engineering News*, Vol. 74, December 9, 1915, p. 1131.

Central mixing plant on Chesapeake and Ohio Northern Ry. delivers concrete to three jobs, as far as 3500 ft. from mixer.

(54) Rolf R. Newman and others, *Concrete and Cement Age*, Vol. 6, March, 1915, p. 3.

The dry mixing of concrete in a batch mixer before adding water.

(55) C. J. Bennett, and others, *Concrete and Cement Age*, Vol. 6, May, 1915, p. 5.

Will mixing concrete too wet cause its eventual failure?

1916

(56) "Central Concrete-Mixing Plant Tried at Baltimore," by G. Y. Carpenter, *Engineering News*, Vol. 76, August 10, 1916, p. 268.

Operation of plant where concrete was delivered for sale. Deliveries made within 30 minutes after leaving mixer or batches rejected. Projects constructed by this method successful. Delivered in contractors' hydraulic-dump-body type of motor truck. Tests at Meade laboratory, Baltimore, Md., show that jigging mortar for periods up to $1\frac{1}{2}$ hours does not materially decrease strength of concrete; small amount of shaking seemed beneficial.

(57) "Desirability of Mixing Concrete Longer than a Minute," tests made by W. D. Uhler, Editorial, *Engineer and Contractor*, Vol. 45, April 19, 1916, p. 301; *Concrete Age*, Vol. 24, April, 1916, p. 30.

(58) "Tests of Concrete Distributed by Short Chutes," by E. McCullough, *Proceedings*, Nat. Conference on Concrete Road Building, 1914, (1914); *Engineering News*, Vol. 75, p. 802 (1916).

(59) "Effect of Duration of Mixing on Quality of Concrete," by E. McCullough, *Engineer and Contractor*, Vol. 45, April 26, 1916, p. 382.

(60) Report of Committee VIII on Mixing and Placing Concrete, *Proceedings*, Nat. Conference on Concrete Road Building, p. 148 (1916).

Recommends speed of mixing drum, number of revolutions and length of time for mixing tests at Lewis Institute on effect of mixing concrete ½, ¾, 1, 1½ and 2 minutes.

(61) "Concrete, Plain and Reinforced," by Taylor and Thompson, p. 173, published by John Wiley and Sons, N. Y., 1916.

Tests indicate that cement mortar or concrete can be regaged without injury up to time of initial set. Thereafter strength is reduced. Regaging of mortar that has begun to stiffen should not be permitted.

(62) "Effect of Prolonged Keeping of Concrete in Wet Condition on Its Subsequent Shrinkage on Hardening in Air," by M. Rudoloff, *Mitteilungen*, Kgl. Materialprüfung, Vol. 34, p. 2 (1916); *Journal*, Soc. Chemical Ind., Vol. 35, p. 1110 (1916).

(63) "Should More Than One Mixture be Used on Buildings?" (letter) by A. M. Wolf, *Concrete*, Vol. 8, No. 5, May, 1916, p. 231.

Advocates reduction of number of classes of concrete in one project to absolute minimum to simplify inspection and prevent error of placing one class of concrete in structure where a different class is required. Claims saving in cement is not sufficient to cover delays and disarrangement of contractor's labor organization. (A. A. LEVISON.)

(64) "Mixing Concrete Limes," Sequel to December article; "How to Arrange the Concreting Plant on the Average Job," by W. W. Hay, *Cement World*, Vol. 10, No. 1, April, 1916, p. 44.

(65) "Recent Development in Building of Concrete Roads," W. D. Uhler, (Paper read before March, 1916, Convention of Am. Road Builders Assn. in Pittsburgh), *Concrete Age*, Vol. 24, No. 1, April, 1916, p. 30.

Recommend minimum of one minute mixing time and speed of mixer not to exceed 16 r. p. m. and not less than 10 revolutions per batch. Retempering should be prohibited. Have no preference for boom and bucket method of placing concrete as against chute. (A. A. LEVISON.)

(66) "Give More Time to Mixing," A. M. Wolf, *Cement World*, Vol. 10, No. 5, August, 1916, p. 12.

(67) "Lawrence Central Bridge Built from Four Separate Mixing Plants," *Engineering Record*, Vol. 74, No. 14, September 30, 1916, p. 415.

Four separate plants located as follows: One on each of two approaches and one on each bank with construction trestle connecting. Each approach plant consisted of a 1-yd. mixer and tower with chuting equipment used with a 1:3 slope. For river arches 1-yd. mixers discharged directly into buckets on flat cars on the construction trestle; 36,000 cu. yd. of concrete involved. (A. A. LEVISON.)

(68) "Bituminous Concrete Paving in Montclair, N. J.," *Municipal Journal*, Vol. 41, No. 22, November 30, 1916, p. 671.

Stretch of 10,000 ft. of street—upper Montclair Ave. which is being paved with bituminous concrete on a Portland-cement concrete base. Adjusting a street to steep side hill.

The article includes a brief paragraph on measuring, mixing, and placing the concrete for the pavement base. Inasmuch as the materials were piled on the subgrade and measured in wheelbarrow the methods described are too obsolete to be of present interest. (R. W. CRUM.)

(69) Working Men in a "Figure 8." *Cement Era*, Vol. 14, No. 12, December, 1916, p. 36.

(70) Welland Ship Thorold Lake Ontario, *Engineering Record*, 210c, 1916, Vol. 76, No. 17, pp. 490–94.

Contractors methods on Welland Ship Canal work; traveling concrete tower introduced on lock construction rivaling that of Panama; central crushing plant utilizes heavy rock excavation.

(71) "Some Features of Concrete Work on Subway Construction, New York City," by Robert Ridgway, *Proceedings*, Am. Concrete Inst., Vol. XII, p. 60 (1916).

Inspection of cement and concrete aggregates. Mixing and placing concrete; precautions against freezing; forms; placing exterior concrete for the Harlem River tubes.

The placing of concrete by means of compressed air is described. The machine used was originally designed for both mixing and placing of the concrete. The materials were fed into the discharge pipe by means of an air-tight drum and inverted cone. It was expected that the action of the compressed air in blowing the materials from the lower end of the cone would give the concrete sufficient mixing. Twelve small compressed air inlets were provided near the top and bottom of the cone for mixing by agitation but were not used. Mixing in this way was a failure and it was found necessary to mix the concrete in a batch mixer, before introduction into the compressed air system. The transportation part of the process was successful. The point of deposit farthest from the mixer was about 500 ft. Initial air pressure of about 100 lb. was used. The time required to discharge a two-bag batch of concrete over 500 ft. varied from 30 to 40 seconds. (R. W. CRUM.)

(72) "Essential Features for Successful Construction of Concrete Roads," by W. M. Acheson, *Proceedings*, Am. Concrete Inst., Vol. XII, p. 458 (1916).

Foundation course on sub-base, materials, mixing, finishing and curing construction, workmanship and results described.

The paper contains a brief statement of good practice in mixing concrete as in vogue in 1916. The number of revolutions of the mixer drum as related to the speed is given as the most important item and the amount of water of second importance. The idea expressed being that if the mixer is run at the right speed for the right number of revolutions, the water factor will take care of itself if the concrete is a "quaky" mixture, not wet enough for the mortar to run away on the subgrade, but plastic enough to be easily worked. A minimum of 12 revolutions and a minimum mixing time of 55 seconds is recommended. (R. W. CRUM.)

1917

(73) "Central Concrete Mixing Plant and Why it Failed," by F. H. Hill, *Electric Railway Journal*, Vol. 50, August 18, 1917, p. 275.

(74) "Auto Engines in Home-Made Dinkeys Save Money on Rush Job," *Engineering News-Record*, Vol. 79, December 13, 1917, p. 1120.

Truck used to haul concrete train in placing 135,000 cu. ft. of concrete in dams at Huntington Lake, Calif.

(75) "Motor Trucks Spout Concrete and Carry Dump Buckets," *Engineering News-Record*, Vol. 79, December 27, 1917, p. 616.

Truck used for hauling mixed concrete in elevation of Chicago and Western Indiana Ry., Chicago, and chute attached to truck for dumping into forms.

(76) "How Long Should Concrete be Mixed?" Editorial, *Concrete*, Vol. 11, August, 1917, p. 52.

(77) "Mixing Concrete 90 Seconds," *Cement and Engineering News*, Vol. 29, June, 1917, p. 160; *Pennsylvania Highway News*, March, 1916.

Tests made by Pennsylvania Highway Dept. on Bethlehem-Allentown Road.

(78) "Field Tests of Concrete for New York Subway," by J. G. Steinle, *Proceedings*, Am. Concrete Inst., Vol. XIII, p. 95 (1917).

(79) "Effect of Grading of Sands and Consistency on Strength of Plain and Reinforced Concrete," by L. N. Edwards, *Proceedings*, Am. Soc. Testing Mats., Vol. XVII, Part II, p. 331 (1917).

(80) "Best Practice in Concrete Road Construction," by H. E. Breed, *Concrete Age*, Vol. 26, No. 3, June, 1917, p. 23.

Discusses grades, accidents on 16-ft. roads, specifications, the mix, and tests.

(81) Development of Milwaukee Co. Highways Cost of Maintenance, 1½ minute Mix Demanded, H. J. Kuelling, *Cement Era*, Vol. 15, No. 2, February, 1917, p. 52.

Batch counter and timer used.

(82) "Review of Final Report of Joint Committee on Concrete and Reinforced Concrete" (composed of members of A.S.C.E.; A.S.T.M.; A.R.E.A.; P.C.A., and A.C.I.). *Cement World*, Vol. 10, No. 11, February, 1917, p. 28.

1918

(83) "Concrete Engineers Handbook," by Hool and Johnson, p. 232, McGraw-Hill Book Co., N. Y., 1918.

The harmful effect of regaging is often less pronounced than is commonly believed and exceptions to the general rule prohibiting regaging may be made under some circumstances. Data from U. S. Bureau of Public Roads and L. C. Sabin indicate that strength of portland cement mortars is not injuriously affected by allowing them to stand for periods of from one to three hours and then regaging.

The most pronounced effect of regaging of mortars and concretes is in the direction of retarding the set and delaying the hardening. Also a detrimental effect upon adhesive strength of mortars to stone is noted. Substantiating data quoted from Sabin, Candlot, McCullough. (R. W. CRUM.)

(84) "Treatise on Masonry Construction," by I. O. Baker, p. 100. John Wiley and Sons, N. Y., 10th Edition, 1918.

Retempering makes mortar easier to handle. Increases time of setting and usually weakens cement mortar. Retempered mortar not recommended for use.

(85) "Effect of Time of Mixing on Strength and Wear of Concrete," by Duff A. Abrams, *Proceedings*, Am. Concrete Inst., Vol. XIV, p. 22 (1918); Discussion, ***Canadian Engineer***, July and August, 1918.

September 12, 1918, Tests at Lewis Institute on concrete of wide range of mixes, consistencies, etc.; mixed 15 seconds to 10 minutes in 3½-cu. ft. mixer. Effect of grading of aggregate and rate of rotation of drum studied. Comparisons made between hand and machine-mixing and between strength and wear of concrete.

(86) "Motor Trucks Deliver Mixed Concrete Three-Fourths Mile," *Engineering News-Record*, Vol. 61, November 28, 1918, p. 1000.

Concrete hauled up to 1 mile at Edison Park, Ill., with maximum time of haul of 20 minutes. Resulting concrete presented good appearance and was satisfactory.

(87) "Five Mile Road Job Served by Central Mixing Plant," *Concrete*, Vol. 13, August, 1918, p. 46.

(88) "Effect on Concrete of Consistency and Time of Mixing," by Duff A. Abrams, *Concrete*, Vol. 13, No. 4, October, 1918, p. 122.

Abstract of paper presented at convention of Amer. Concrete Inst., June, 1918.

(89) "Effect of Time of Mixing on the Strength of Concrete . . . Chicago, Structural Materials Research Laboratory," by Duff A. Abrams, reprinted from *Canada Engineer*, July 25, August 1, 8, 1918; paper before Am. Concrete Inst., Fourteenth Annual Convention, Atlantic City, N. J., June 29, 1918.

1919

(90) "Cost of Highway Concrete Delivered Wet by Trucks," *Engineering News-Record*, Vol. 82, May 1, 1919, p. 870.

(91) "Minute Concrete Mix Subject to Some Doubt," by Herbert A. Davis, (Reply to editorial in *Engineering News-Record* of November 28, 1918), *Engineering News-Record*, Vol. 82, No. 6, February 6, 1919, p. 300.

(92) "Bettering Concrete by a New Mixing Method," by N. C. Johnson, *Engineering News-Record*, Vol. 82, No. 26, June 26, 1919, pp. 1266–1270.

Recommends that concrete be mixed in a bowl by centrifugal force. Bowl rotates rapidly and blades are inserted from above to hasten mixing action. Claims violence of centrifugal mixer brings about more intensive hydration, greater uniformity and better mixing action. Statement is made that conventional types of concrete mixers were ineffective. (A. A. LEVISON.)

(93) "Fundamentals in the Make-Up of a Concrete Mixture," by A. N. Talbot, *Engineering News-Record*, Vol. 82, May 1, 1919, p. 869.

Thirteen points discussed before A.R.E.A.

(94) "Time of Mixing," by C. A. Streets, *Concrete Engineer and Contractor Magazine*.

(95) "Influence of Time of Rotation in Mixing Machines on Strength of Concrete," by G. Mahir, *Beton und Eisen*, Vol. 12, p. 41 (1919).

(96) "Further Tests on Time of Mixing Concrete," by J. O. Jones, *Engineering News-Record*, Vol. 82, January 23, 1919, p. 200.

(97) "Effect of Time of Mixing on Concrete Strength," by J. L. Harrison, *Public Roads*, Vol. 9, July, 1928, p. 93; *American Contractor*, Vol. 49, August 25, 1918, p. 20.

Conclusion from data secured is that strength is not increased by longer mixing periods.

1920

(98) "Pro-mixing no Benefit in Concrete," *Engineering News-Record*, Vol. 84, February 12 and March 4, 1920, pp. 335, 473, respectively.

Bureau of Standards test show no advantage on strength of concrete in promixing cement and water before (15 to 30 minutes) adding aggregate.

(99) "Mixing Concrete by Surface Areas on Actual Work," by R. B. Young, *Engineering News-Record*, Vol. 84, January 1, 1920, p. 33; *Canadian Engineer*, Vol. 38, January 1, 1920, p. 101.

Method used for proportioning materials by Hydro-Electric Power Commission.

(100) "Using 6-in. Bank-Run Aggregate on Stevenson Dam," *Engineering News-Record*, Vol. 85, September 30, 1920, pp. 638, 959.

Compressive strength tests at 7 and 28 days on 6-in. cubes with aggregate up to 2½ in.; 6-in. aggregate used efficiently and engineers recommend use of 9 or 10-in. aggregate for large work.

(101) "Fast Road-Building with Concrete Hauled Four Miles," *Engineering News-Record*, Vol. 84, February 5, 1920, p. 280.

Plan of central mixing plant and truck system for building 6-mile road.

(102) "Wet Haulage to Road Excels Dry Haulage to Mixer," *Engineering News-Record*, Vol. 85, August 19, 1920, p. 356; *Engineering and Contracting*, Vol. 54, October 6, 1920, p. 339.

Comparison of two methods determines adoption of central mixing plant and wet batch haulage on concrete road job in Illinois.

(103) "Doesn't Take Army of Men to Build Concrete Roads with Up-To-Date Methods," Iowa State Highway Commission, *Service Bulletin*, Vol. 8, December, 1920, p. 4.

Central mixing plant used for hauls up to 3 miles; about 15 minutes haul. No separating of materials nor trouble in avoiding initial set of concrete until placing.

(104) "1,094 Feet of 18-Foot Road in 8 Hours," *Concrete*, Vol. 17, December, 1920, p. 201.

Construction details of central mixing plant; comparison with paving mixer method.

(105) "Wet Concrete Hauled 3 Miles for Pavement Base," by C. B. Montgomery, *Engineering News-Record*, Vol. 85, November 4, 1920, p. 885.

Concrete flows freely after ½ hr. on trucks.

(106) "Central Mixing Plant Makes New Pavement Record at Big Lake, Minn.," *Municipal and County Engineer*, Vol. 59, November, 1920, p. 21; *Public Works*, Vol. 49, November 6, 1920, p. 434.

(107) "Central Mixing Plant on Concrete Highway," by R. Petersen, *Highway Engineer and Contractor*, November, 1920, p. 21.

Equipment in Cerro Gordo County, Iowa.

(108) "Central Mixing and Proportioning Plants in National Old Trails Road Construction in Illinois," *Engineering and Contracting*, Vol. 54, October 6, 1920, p. 339.

(109) "Central Mixing *versus* Proportioning Plants," *Western Highways Builder*, August 14, 1920, p. 6.

H. W. Horst and Co. plant at Hagerstown, Fayette Co., Ill.

(110) "Central Mix Road Job Near Rudd, Iowa," *Concrete*, November, 1920, p. 187.

1921

(111) "Oversize Construction Plant Demonstrates Value," *Engineering News-Record*, Vol. 86, No. 2, January 13, 1921, pp. 82, 85.

This article describes construction operation on manufacturing plant for Fisher Body Co. at Cleveland, O. 50,000 cu. yd. of concrete involved. Two 1-yd. mixer plants with overhead bins used. One plant fed three towers, and the other plant fed two towers. Overhead bins loaded by conveyors. One plant working 8 hours and the other 9 hours, or a total of 17 plant hours; produced 1065 cu. yd. of concrete, or more than 61 cu. yd. per hour per plant. (Note.—This would mean actual mixing time of approximately 30 to 40 seconds per batch.) (A. A. LEVISON.)

Completed in quick time by concentrating equipment for peak-load construction.

(112) "Tests of Concrete Mixer," by W. K. Hatt, *Proceedings*, Am. Concrete Inst., Vol. XVI, p. 47 (1921).

Tests at Purdue University on 10-cu. ft. mixer. Data on power consumption, strength of concrete, etc.

Mix 1:2:3; mixer 10-S capacity equipped with batch meter and water control. Mixed 158 batches and varied time of mixing from ½ to 1½ minutes.

1. Increasing mixing time, improves strength.
2. Introducing water into drum rapidly and early, improves consistency and strength.
3. When mixer is run 12 r.p.m. and 22 r.p.m., loss of strength is 24 per cent, as compared to 16 r.p.m.
4. Power required to run mixer.
    (*a*) empty ½ H.P.
    (*b*) running and mixing 4 to 5¼ H.P.
    (*c*) mixing complete 3¼ to 5 H.P.
5. Prolonged mixing with absorbent coarse aggregate stiffens mix. Recommends prewetting of such aggregate. (A. A. LEVISON.)

(113) "Tests of a Concrete Mixer," by W. K. Hatt, *Proceedings*, Am. Concrete Inst., Vol. XVII, p. 47, 1921.

Tests made to study action of the Koehring Mixer, No. 105, determine its power, characteristics, effect of time of mixing on consistency and strength of concrete, effect of changing speed of rotation of drum and possibility of producing concrete of proper consistency and strength at an earlier time by changing water control and speed of rotation of drum.

(114) "Proportioning and Making Concrete on Barrett Dam," by H. N. Savage, *Engineering News-Record*, Vol. 87, October 27, 1921, p. 695.

Aggregate up to 6 in. by 14-in. occasional longest dimension used, designed by Fuller and Abrams' method. Tests on 8 by 14-in. cylinders.

(115) "Strength Tests of Pre-Mixed Concrete on Detroit Street Railways," by W. R. Dunham, Jr., *Engineering News-Record*, October 27, 1921.

(116) "Proportioning and Mixing Concrete," Progress Report—Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, Chapt. V, 1921, *Proceedings*, Am. Soc. Testing Mats., Vol. 21, p. 212 (1921); also *Proceedings*, Am. Soc. Civil Engrs., 1921.

1921

(117) "Strength of Concrete at Increasing Intervals After Mixing," by R. C. Durst, *Engineering News-Record*, Vol. 87, November 10, 1921, p. 773; *Cement and Engineering News*, Vol. 34, p. 27 (1922).

Compressive and tensile tests on remixed, tempered, and concrete allowed to stand for a number of hours after mixing, at Univ. of Akron, show very little strength is lost up to the third or fourth hour and an increase in strength is not noticeable after the fourth hour of mixing.

(118) "Strength Tests of Pre-Mixed Concrete on Detroit Street Railways," by W. R. Dunham, Jr., *Engineering News-Record*, Vol. 87, p. 681 (1921).

(119) "Retempering Cement Mortar," Brick—How to Build and Estimate, by W. Carver, 1921, p. 39.

Retempering seriously decreases strength of quick-setting mortars.

(120) "Central-Plant-Mixed Concrete Tested for Maximum Haul," *Public Roads*, December, 1921, p. 22.

Slump and compressive strength of concrete hauled in truck up to $3\frac{1}{2}$ hour. Slump decreased with time; strength not changed.

(121) "Portable Conveyor Fitted to Central Mixing Plant," *Engineering News-Record*, Vol. 87, p. 267 (1921).

(122) "Developments in Plant and Organization for Concrete Road Construction," by C. R. Ege, *Proceedings*, Am. Concrete Inst., Vol. XVII, p. 79 (1921).

Central mixing plants, operation, advantages, and precaution.

(123) "Marketing Ready-Mixed Concrete from Products Plants," by A. J. R. Curtis, *Concrete*, Vol. 18, April, 1921, p. 200.

Advantages, possibilities, precautions in cold and warm weather, time of loading, hauling, discharging, efficiency, and limitations of central mixing plant for marketing ready-mixed concrete.

(124) "Central Proportioning Successful on Minnesota Road," *Concrete*, Vol. 19, September, 1921, p. 125.

Plant and organization of crew to carry operations 2 miles to either side of mixer.

(125) "Comparison of Three Methods of Concrete Road Construction," *Engineering News-Record*, Vol. 87, July 21, 1921, p. 111; *Engineering and Contracting*, Vol. 56, October 5, 1921, p. 334.

Comparison of wheelbarrow, central proportioning and central-mixing-plant methods in building 12 miles of road in Iowa.

1921

(126) "Central Mix Road Job in Iowa," by T. W. Ingemanson, *Concrete*, Vol. 19, November, 1921, p. 187.

Operation of plant with 2-mile haul.

(127) "Central Mixing for Concrete Roads," by C. S. Hill, *Engineering News-Record*, Vol. 87, October 20, 1921, p. 336.

Suitability for road work, segregation, consistency, difficulties, and comparison of strengths of road mix and central mix concrete. Satisfactory, but work should be carefully directed.

(128) "Central Mixing for Five-Mile Hauls," by R. Petersen, *Concrete*, Vol. 18, February, 1921, p. 50.

Advantages over paving mixer on work requiring haul of 4 or 5 miles.

(129) "Central Mixing a Success," by B. H. Piepmeier, *Concrete*, Vol. 18, February, 1921, p. 90.

Use on Illinois roads desirable; better supervision and more uniform results; little trouble experienced in concrete setting before delivery in hauls of 1 to 5½ miles.

(130) "Tests of Central Plant Mixed Concrete for Maximum Safe Haul," *Public Roads*, Vol. 4, December, 1921, p. 22; *Engineering and Contracting*, Vol. 57, February 1, 1922, p. 101; *Good Roads*, Vol. 62, March 8, 1922, p. 148.

Slump and strength tests by Bureau of Public Roads of concrete hauled for periods after mixing up to 3 hours.

(131) "Central Plant Mixed Concrete Tested for Safe Haul," by J. W. Brooks, *Contractors and Engineers Monthly*, Vol. 4, April, 1922, p. 48.

Tests for maximum safe haul for concrete.

(132) "Average and Maximum Runs in Concrete Paving," *Engineering News-Record*, Vol. 86, February 3, 1921, p. 223.

Road job in Minnesota on which record of 2,196 sq. yd. of pavement was laid in 10 hours by means of central mixing plant; maximum haul 3¾ miles.

(133) "Concrete Hauled Three Miles from Central Mixing Plant," *Engineering News-Record*, Vol. 87, August 4, 1921, p. 176.

Twelve miles of pavement on desert from two mixer set-ups, causing maximum haul of 3 miles. Chief problem was to prevent separation of cement and aggregate in transit. Factors affecting this were roughness of road, time of hauling, amount of water used in mix and grade of sand. Concrete in which segregation took place not used.

(134) "Using Flow Table in Central Mixing for Concrete Roads," by G. M. Williams, *Engineering News-Record*, Vol. 87, December 15, 1921, p. 993.

Similarity of jolting on flow table with that of hauling over roads. Recommends study of segregation as well as consistency with flow table, as aggregate will flow beyond mortar line or mortar will flow beyond coarse aggregate mass if too wet.

(135) "Road Construction Plants," by B. H. Piepmeier, *Good Roads*, Vol. 21, May 25, 1921, p. 273; *Mechanical Engineering*, Vol. 43, June, 1921, p. 386; Abstract, *Engineering News-Record*, Vol. 86, June 25, 1921, p. 949; *Municipal and County Engineering*, Vol. 61, sup., July, 1921, p. 21; *Public Works*, Vol. 51, July 23, 1921, p. 71.

Recommends study of delivering mixed concrete to the road job. Expresses hope for ideal, simple and uniform central mix plant design. Recommends truck haul on pneumatic tires for delivering concrete.

Claims concrete paving mixers should be made smaller, more efficient, larger capacity, and do the mixing in 15 seconds instead of 60 seconds. Criticizes paving mixers because inside of drum is hidden from operator. (A. A. LEVISON.)

(136) "Combination Central Material and Mixing Plants on Illinois Highway Work," *Engineering and Contracting*, Vol. 56, October 5, 1921, p. 333.

(137) "Concrete Road Mix Proportioned at Central Plant," by H. T. Tuthill, *Engineering News-Record*, Vol. 86, April 7, 1921, p. 595.

(138) "Central Mixing Plant Used for Building Concrete Pavements at West Allis, Wis.," *Concrete Highway Magazine*, Vol. 5, December, 1921, p. 149.

(139) "Mechanical Devices Save Labor at Novel Central Mixing Plant," by C. N. Slaymaker, *Concrete Highway Magazine*, Vol. 5, November, 1921, p. 139.

Equipment and labor distribution.

(140) "Concrete Hauled from Central Mixing Plant on State Highway Job in Walla Walla County, Wash.," by E. R. Hoffman, *Concrete Highway Magazine*, Vol. 5, January-February, 1921, p. 5.

(141) "Contractor Makes Ingenious Use of Available Equipment for Central Mixing Plant," *Concrete Highway Magazine*, Vol. 5, January-February, 1921, p. 7.

1922

(142) "Hauling of Concrete from Central Mixing Plants," *Engineering and Contracting*, Vol. 57, June 7, 1922, p. 536.

(143) "Unusual Central Mixing Plant," *Successful Methods*, February, 1922, p. 14.

Conveyors fill hoppers on Iowa road job.

(144) "Segregation as It Applies to Tanks as Segregating or Mixing Devices," by C. Catlett, *Concrete*, (CMS), Vol. 20, May, 1922, p. 119.

(145) "Contractor Finishes Second Year with Central Mixing Plant on Jefferson Highway Contract," by H. E. Chard, *Concrete Highway Magazine*, Vol. 6, February, 1925, p. 45.

Equipment described for plant in Minnesota.

(146) "Special Concrete Specified for Jamaica Bay Viaduct," *Engineering News-Record*, February 9, 1922.

(147) Discussion of Report of Joint Committee on Time of Mixing Concrete, *Proceedings*, Am. Concrete Inst., Vol. 18, pp. 331, 351 (1922).

(148) "To Avoid Variable Concrete Due to Variable Sand Wetness," by R. L. Bertin, *Engineering News-Record*, June 22, 1922, p. 1046.

New method of mixing proposes inundating sand before dumping in mixer thus keeping moisture content constant.

The coarse aggregate carries a certain amount of water but it was found by keeping it uniformly moistened that this amount was small and fairly uniform, and that no compensation was necessary since there was but a slight variation.

To correct for variable moisture in fine aggregate a cylindrical measuring container to hold saturated sand was designed and tests made, the conclusions of which are as follows:

1. The amounts of water and sand in successive batches are practically constant.
2. The plasticity of the concrete as determined by the slump test showed only slight variations.
3. The cement factor in successive batches is nearly constant.
4. The amount of concrete in each batch measured by volume or weight is nearly constant.
5. The strength of the concrete tested at 28 days is fairly uniform. (A. A. LEVISON.)

1923

(149) "Standardization of Horizontal Non-Tilting Drum Concrete Mixers," *Good Roads*, Vol. 65, August 1, 1923, p. 43.

Provisions for standardization approved by joint committee on construction equipment in session with members of Associated General Contractors and representatives of mixer manufacturers.

Mixer manufacturers decide upon standardization of mixers as to capacities, types, auxiliary equipment ratings. Plate to be attached showing conformity to requirements. (A. A. LEVISON.)

(150) "Proper Proportioning of Concrete and Predetermination of Its Compressive Strength at Place of Construction," by O. Graf, *Gesundheits-Ingenieur*, Vol. 46, June 30, 1923, p. 243.

Influence of size of sand grains, influence of water additions, etc.

(151) "Report on Field Tests and Methods Used in Building Construction to Obtain Concrete of Specified Strength," by J. G. Ahlers, *Proceedings*, Am. Concrete Inst., Vol. XIX, p. 114 (1923).

This report discusses the use of pre-mixed aggregates and the necessary tests to determine the practicability of so-called "Ready Mix," together with an attempt to obtain a uniform concrete aggregate with a required strength. An average fineness modulus of fourteen barge loads of ready mix aggregates shows a variation of 4.95 5.75. The average strength test cylinders from these barges show no relation to the fineness modulus.

From experience on this building operation, it seems that the use of ready mix aggregates with a uniform fineness modulus is reasonably sure to give uniform results in the strength of the concrete. It seems safe to predict that with a uniform aggregate, uniform concrete, and definite rules for building superintendents as to water and mix, fairly uniform results should be obtained.

It is necessary in all field work to have the methods as simple and without complication as possible as it will be a long time before any superintendent or field engineer will be able to make his own design of the concrete mix. (A. A. LEVISON.)

(152) "Variables in Concrete from Construction Standpoint," by W. P. Bloecher, *Proceedings*, Am. Concrete Inst., Vol. XIX, (1923) p. 100; *Highway Engineer and Contractor*, Vol. 9, August, 1923, p. 45.

Discusses variables in concrete and gives some results of job testing.

(153) "Central Mixing Plant for Dallas, Tex.," Leaflet published by Smith Bros., Inc.

Advantages of central plant-mixed concrete. Claims loss smoke, grime and congestion, and more enduring concrete.

(154) "Mixing Plant Saves Time and Money," *Cement and Engineering News*, Vol. 35, July, 1923, p. 26.

Layout and operation of plant.

(155) "Central Mixing Plant for City Work," by E. E. Bauer, *Engineering and Contracting*, Vol. 59, May 2, 1923, p. 975.

(156) "Central Mixing Plant Used in Widening Macadam Road with 3-ft. Shoulders," by L. A. Reindollar, *Engineering News-Record*, Vol. 90, January 11, 1923, p. 85.

(157) "Electrically Operated Central Mixing Plant," *Engineering and Contracting*, Vol. 60, October, 1923, p. 883.

(158) "Haulage of Lean Mixture of Concrete," by C. C. Wiley, *Engineering and Contracting*, Vol. 59, May 2, 1923, p. 985.

(159) "Mixing and Delivering Concrete for City Pavements," by F. S. Besson, *Concrete*, Vol. 22, April, 1923, p. 137.

(160) "Modern Mixing Methods," by A. W. Allen, *Chemical and Metallurgical Engineering*, Vol. 29, December 31, 1923, p. 1186; *Engineering and Contracting*, Vol. 61, May 28, 1924, p. 1160.

Controlled raw mixtures and efficient mixing at central plant in Los Angeles produces better and cheaper sand-lime mortar for building. Equipment described.

(161) "Ideal Layout for Central Mixing Plant," *Highway Engineer and Contractor*, January, 1923, p. 47.

Powell-Gauen Co., Monroe County, Ill.

(162) "Central Mixing and Labor Saving Arrangement for Alley Paving," *Engineering and Contracting*, November 7, 1923, p. 971.

(163) "Palo Alto, Calif., Municipal Paving Plant," *The American City*, February, 1923, p. 112.

(164) "Concrete for Streets in Industrial City Mixed at Central Plant," by B. D. Budd, *Concrete Highway Magazine*, Vol. 7, March, 1923, p. 55.

Plant layout, hauling equipment, etc., at Petersburg, Va.

(165) "Influences of Methods of Proportioning and Mixing," by R. B. Young, *Proceedings*, Am. Soc. Testing Mats., Vol. 23, Part II, p. 175 (1923); *Engineering News-Record*, Vol. 91, July 12, 1923, p. 54.

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(166) "Proportioning and Mixing Concrete," Report of Joint Committee on Standard Specifications for Concrete and Reinforced Concrete, 1924, *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part I, p. 323 (1924); *Proceedings*, Am. Soc. Civil Engrs., 1924.

(167) "Better Concrete: Water-Cement Ratio," by D. H. Dixon, *Turner Constructor*, 1924, *Concrete*, Vol. 24, June, 1924, p. 243.

Discusses methods of designing concrete mixtures developed at the Structural Materials Research Lab.

(168) "Control of Concrete for University of Illinois Stadium," by Slater and Brown, *Proceedings*, Am. Concrete Inst., Vol. XX, p. 403 (1924).

(169) "Abrams' Theory in Practice," by P. E. Kressly, *Western Highways Builder*, May and June, 1924.

(170) "Old and New Methods of Constructing Concrete Bridges," by J. B. Hunley, *Proceedings*, Am. Concrete Inst., Vol. XX, p. 259 (1924); *Engineering and Contracting*, March 26, April 23, and May 28, 1924.

Specifications of the Cleveland, Cincinnati, Chicago & St. Louis Railroad in use in 1898 for the mixer to be used in concrete bridges were:

Footings.—1 part Louisville cement, 2 sand, 5 gravel.

Abutments and Wings.—1 part Portland cement (Buckeye or Alpha), 2½ sand, 6 gravel or stone.

Arch Ring.—1 part Alsen Portland cement, 2 sand, 5 limestone chips.

Parapet Walls.—1 part Alsen Portland cement, 2 sand, 6 stone. All exposed surfaces were to be faced with mortar, 1 cement, 2½ sand, 2 to 3 in. thick.

In 1902 the specifications were issued and established a proportion of 1:2:4 where natural cement was used in foundations and for piers and abutments of portland cement 1:2½:4 and contained this clause:

It is understood that the proportions of stone and gravel are approximate and may vary with the character of the materials and must always be such that the mortar will fill all the interstices in the stone when rammed. The concrete shall be of such consistency that the water shall just flush to the surface when rammed.

In 1905 new specifications were issued on account of the discontinuance of use of natural cement. The new specifications advocated wetter mixes, and proportions arbitrarily fixed at 1:2:4, 1:3:6, etc. and premixed aggregates were permitted to be used.

In 1910 the specification for cement was revised and that for the aggregate slightly modified, but the consistency was such that when dumped in place it will not require much tamping.

In 1915 the use of tower and chute came into general use and mixes became still wetter. The specifications requiring the concrete shall be a wet mixture of such consistency that it will flow freely on a slope of four horizontal to one vertical.

All of these specifications were in line with general practice but the results were not satisfactory; costs, quality, etc., would vary to such an extent that it was always a gamble.

In 1922 proportioning concrete as outlined by D. A. Abrams was begun and it was very highly satisfactory. A concrete of predetermined strength and of uniform quality was produced.

The Abrams' method is based on the use of a minimum amount of mixing water, and a means (F.M.) of grading and proportioning the aggregates. (A. A. LEVISON.)

(171) "Field Tests of Concrete," by Ahlers and Walker, *Proceedings*, Am. Concrete Inst., Vol. XX, p. 358 (1924).

Results of field tests on five reinforced concrete buildings in New York City and vicinity in which concrete was prepared in accordance with scientific methods of designing mix and samples taken to endeavor to improve uniformity and quality of resulting concrete.

This paper covers completely tests made from actual jobs during the Summer and Fall of 1923 in New York City and the Structural Materials Research Laboratory, Lewis Inst., Chicago.

These tests covered five separate jobs and required the manufacture of 650 6 by 12-in. test cylinders, and a sieve analysis of 190 samples of aggregate and numerous determinations necessary to furnish complete information from which an intelligent analysis of the test results could be made.

CONCLUSIONS:

1. Concrete 6 to 18 per cent stronger than designed was produced;

2. 75 per cent of test specimens would fall within 20 per cent of average strength;

3. A study of the proportions and materials used should enable the engineer to estimate within 20 per cent the average strength of concrete when made in accordance with practices followed on these jobs;

4. Water ratio offers a practical basis for estimating strength if suitable aggregates are used;

5. The fineness modulus is an accurate "yard stick" for measuring the grading of aggregate to determine proportions;

6. The values of fineness modulus given in "Table 3, Bulletin 1, of the Structural Materials Research Lab." may be satisfactorily applied to building construction;

7. Concrete designed under conditions encountered in this investigation gave strengths well above the values computed on the same basis as the "Joint Committee Tables of Proportions";

8. The variations in strength shown by individual specimens for different batches were the result of accidental variations in proportions. The variations were not due to test methods employed;

9. A device which will insure a uniform quantity of aggregate from batch to batch will be of material assistance in securing concrete of uniform strength. Hoppers having vertical sides and provided with *mechanical strike-offs* offer great advantages over present methods.

UNIFORMITY IN THE VOLUME OF SAND CAN BE MAINTAINED BY THE INUNDATION METHOD OF MEASUREMENT:

10. Uniform aggregate should be furnished throughout duration of job.

11. It is feasible to modify proportions to compensate for variations occurring in scow loads or lots of considerable size.

12. On large jobs aggregate tests should be made to determine economical proportions.

13. Scientific control can best be applied by using a testing organization outside that of owner or contractor.

14. This investigation shows importance of job tests to determine strength of concrete used. Definite strengths can be obtained by (*a*) rigid inspection and (*b*) tests of the concrete. (A. A. LEVISON.)

(172) "How Big Four Proportions Concrete," *Railway Engineering and Maintenance*, October, 1924.

(173) "Concrete Strength Controlled by Proportioning Device," *Concrete Products*, Vol. 27, November, 1924, p. 55.

Use of device by engineers and contractors; uniform results obtained.

(174) "New Type of Concrete Mixer Mounted on Truck," *Engineering and Contracting*, Vol. 62, December 24, 1924, p. 1392.

Mr. Charles Payne of 27 Fulton Ave., Waukegan, Ill., is inventor of the novel concrete mixer.

This is one of the early transit mix truck ideas with a drum and rotating shaft taking its power from the trucks. (A. A. LEVISON.)

(175) "Small Mixer Mounted on Ford Chassis," *American Contractor*, Vol. 5, November 22, 1924, p. 33.

Archer Auto Mixer.

(176) "Mixer Standards Make Progress," *Constructor*, Vol. 6, November, 1924, p. 35.

Eleven prominent manufacturers of concrete mixers have accepted the standards in their entirety. (A. A. LEVISON.)

(177) "Sand Company Markets Ready-Mixed Concrete," *Concrete Products*, Vol. 26, May, 1924, p. 59.

Handling, equipment, cost, etc.

(178) "Ready Mixed Concrete," *Cement and Engineering News*, 1924; *Engineering and Contracting*, Vol. 61, April 23, 1924, p. 857.

Practicability and advantages.

(179) "Wet-Mixed Concrete as Sand and Gravel Plant Side Line," *Rock Products*, Vol. 27, November 1, 1924, p. 60.

Describes plants at Kankakee, Danville, Los Angeles, Dallas, Fort Worth, etc.

(180) "Central Mixing Plant in Los Angeles," *Concrete*, Vol. 25, September, 1924, p. 110; *Engineering and Contracting*, Vol. 62, October 22, 1924, p. 892.

Uniform Mixing Concrete Co., Inc., of Los Angeles.

(181) "Can Dealers Sell Pre-Mixed Concrete," by C. H. Miller, *Concrete*, Vol. 25, September, 1924, p. 110; *Canadian Engineer*, Vol. 47, September 30, 1924, p. 389.

Possibilities of retail dealer with ready-mixed concrete.

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(182) "Central Mixing Plants," by W. E. Hart, *Proceedings*, Am. Concrete Inst., Vol. XXI, p. 188 (1925); *Engineering and Contracting*, Vol. 63, June 24, 1925, p. 1387, editorial, p. 1359.

(183) *National Sand and Gravel Bulletin*, Vol. 6, p. 11 (1925).

Segregation, time of set and retempering of concrete; advantages, limitations, crews and equipment, measurement by weight, bulk cement and truck problems. A general discussion of these problems with a definite advice to proportion by weight. (A. A. LEVISON.)

(184) "Advantages of Central Mixing Plants for Concrete and Mortar, *Engineerind and Contracting*, Vol. 63, June 24, 1925, p. 1359.

(185) "Central Mixing Plants for Concrete," by C. R. Miller, *Concrete*, Vol. 26, March, 1925, p. 87.

Operation, cost and selling price of ready-mixed concrete.

(186) "Concrete Mixing and Distributing Plant," *Surveyor*, Vol. 67, January 30, 1925, p. 142.

Manufactured by Stothert and Pitt, Ltd., Bath, for Stewart and McDonnell for use in construction of Sutton by-pass road.

(187) "Hauling Wet Mix," *Central Constructor*, Vol. 2, March, 1925, p. 5.

After 3 year experience, C. F. Lytle Construction Co., Sioux City, thoroughly committed to advantages of system.

(188) "Combined Haulage on Concrete Road Job," *Contractor and Engineer Monthly*, Vol. 10, March, 1925, p. 61.

(189) "Four-Mile Belt Conveyor System," *Engineering and Contracting*, Vol. 63, April 17, 1925, p. 841.

Conveyance of concrete from central mixing plant.

(190) "Selling Mixed Concrete," by C. H. Miller, *Contractor and Engineer Monthly*, Vol. 10, p. 53 (1925).

Six central concrete mixing plants operated as commercial propositions: three in Illinois, one in Oklahoma City, and one in Philadelphia, Pa.

(191) "Central Mixed Concrete Plants," by R. M. Quigley, *National Sand and Gravel Bulletin*, November, 1925, p. 15.

Economy and practicability.

(192) "Concrete Making Machinery," by W. N. Twelvetrees, Van Nostrand Co., New York, 1925.

Appliances and plant for testing and preparing constituent materials and for distribution of mixed concrete. (A. A. LEVISON.)

(193) "New Central Mixing Plant," *Municipal Improvements*, Vol. 4, October, 1925, p. 10.

Plant used on Canadian road job.

(194) "Central Mixing Plant Builds Pavements in Denver and Royal Gorge R. R. Yards," by C. B. Daniels, *Concrete Highway Magazine*, Vol. 9, July, 1925, p. 174.

(195) "Concrete Mixer Mounted on a Motor Truck That Was Recently Invented by a Retired Waukegan, Ill., Contractor," *American Contractor*, Vol. 6, February 7, 1925, p. 33.

(196) "The 'Aero' Mixer and Its Operation," *Engineering and Contracting*, Vol. 63, February 25, 1925, p. 392.

A new concrete mixing machine has been developed, known as the "Aero," which has been patented. Into a projecting end of a rotating drum, aggregate is charged at a rate which is automatically adjusted to the capacity of the machine. Water is added under perfect regulation. As the moistened aggregate reaches the drum, it is exposed to the cement, which is introduced into the drum at the opposite end, by means of a fan which produces a cloud of the finest cement particles within the drum. The quantity of cement added is adjusted and automatically maintained so long as cement is supplied to the hopper.

Within the drum the moistened aggregate now acquires a film of cement. The coarse and fine aggregates are perfectly mixed. A homogeneous product results, each grain of aggregate having an unbroken coat of cement. The resulting concrete is said to be much stronger and less expensive than ordinary concrete. Its resistance to bending 400 per cent higher than ordinary concrete. This method also permits using sea sand, powder sand, ashes, clinker and cinders. (A. A. LEVISON.)

(197) "Economic Waste of Non-Standard Mixers," by P. A. Koehring, *Engineering and Contracting*, Vol. 64, September 25, 1925, p. 531.

Discusses waste from lack of standardization, development of paving mixers and suggestions for standardization.

Suggests setting up a national standard through an organization having official standing. All mixers to be plated, as approved by the Associated General Contractors' Standard. (A. A. LEVISON.)

(198) "New Type of Mixer Mounted on Truck," *Engineering and Contracting*, Vol. 62, December 24, 1924, p. 13.

(199) "The New Ehrlick Mixer," *Revue de Matériél de Construction et de Travaux Publics*, Vol. 28, January, 1927, p. 25.

Graphic description of mixing methods.

(200) "Design of Concrete Mixtures Under Field Conditions," by T. P. Watson, *Proceedings*, Am. Concrete Inst., Vol. XXI, p. 31 (1925); *Engineering and Contracting*, Vol. 64, August 19, 1925, p. 419.

Data on experience in field control on Beck's Run Bridge near Pittsburgh.

(201) "Inundation Method for Concrete," *Concrete Products*, Vol. 29, August, 1925, p. 57.

Blaw-Knox inundation method for proportioning concrete to obtain uniform product through the medium of accurate water and aggregate control; bulking effect of moisture discussed.

(202) "Theory Must Aid Practice in Concrete Making," by C. P. Richardson, *Proceedings*, Am. Concrete Inst., Vol. XXI, p. 24 (1925).

(203) "Specifying Concrete to Meet Strength Requirements," by F. R. McMillan, Associated General Contractors of America, 1925.

(204) "Predetermining Concrete Strength on Park Bridges," by W. F. Welsch, *Engineering News-Record*, October 15, 1925.

(205) "Control of Concrete on the Job," by F. Von Emperger, *Beton und Eisen*, Vol. 24, July 5, 1925, p. 209.

(206) "Sheet Asphalt Mixture Research," by H. W. Skidmore, *Engineering and Contracting*, Vol. 63, April 1, 1925, p. 693.

Comparative value of various fillers in voids in Lake Michigan sand which is extensively used in paving mixtures. Methods of determining voids, relation of voidage to sand grading, practical application of voiding studies and practical demonstration of untenability of surface area theory.

(207) "Practical Methods for Design of Concrete Mixtures," by T. P. Watson, *Engineers and Engineering*, Vol. 42, March, 1925, p. 61.

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(208) "Prehydration of Cement in New Method of Concrete Mixing," *Engineering News-Record*, May 27, 1926, p. 850.

Contributed speed and good concrete to work on Baltimore Filter Plant—centrifugal pump basic equipment.

The advantages of prehydration are:

1. No lumps in concrete.
2. Consistently good quality of concrete.
3. Provides facilities for handling grout.
4. Decided saving in mixing time—15 seconds required.
5. Gives uniform distribution throughout the mass when using hydrated lime.
6. Permits economical plant layout by having the hydrating machine at mixer or at a distance as conditions demand.

This hydrating machine is made by mounting a cylinder drum vertical and having an outlet at its bottom which is connected to the suction side of an ordinary volute pump. This pump is, in turn, directly connected to a motor. The discharge of the pump is arranged so that it may connect either with a return line to the top of the cylinder drum or hydrating chamber, or by valve manipulation with a pipe leading to the mixer.

The machine is located in the cement shed. The pump operates continuously; a predetermined amount of water is admitted to the hydrating chamber through a valve. It circulates out of bottom of chamber through pump and back into chamber; into this circulation cement is added. After twelve seconds, a valve is closed and another valve opened, permitting the pump to force the slurry mixer. (A. A. LEVISON.)

(209) "How Long Should Concrete Be Mixed?" *The Canadian Engineer*, June 29, 1926, p. 717.

Contains statement from studies by Duff Abrams and California Highway Commission.

(210) "Concrete Mixing Tests—Time and Capacity Studies," by C. S. Pope, *California Highways*, Vol. 3, February, 1926, p. 5.

More than 1 min. mixing of no particular value.

(211) "Water-Cement Ratio Specification for Concrete," by McMillan and Walker, *Proceedings*, Am. Soc. Civil Engrs., Vol. 51, September, 1926.

(212) "Control of Concrete in America," by A. Kleinlogel, *Beton und Eisen*, No. 11, June 5, 1926.

Field control on construction work; water-cement ratio described.

(213) "Job Control of Concrete," by H. Held, *Beton und Eisen*, Vol. 24, January 5, 1926, p. 17.

(214) "Control of Concrete on the Job," by Amos, *Beton und Eisen*, Vol. 25, March 20, 1926, p. 116.

(215) "Assuring Quality on the Job," *Beton und Eisen*, Vol. 25, April 5, 1926, p. 131.

Discussions by Morsch, Melan, Hager, Doerr, Stern and others.

(216) "Effect of Manipulation on Strength of Field Concrete," by G. W. Hutchinson, *Engineering News-Record*, Vol. 96, February 11, 1926, p. 246.

Describes the effect of manipulation in placing of concrete as disclosed by the compressive strengths of cores taken at points 18 in. from the edge, at the middle, and one-third points from concrete pavements. Two series of four cores each were taken on 27 projects. In these tests the average strengths of the cores at the edges where the concrete is practically worked by hand was about 3 per cent less than that of the cores at the one-third point where the concrete is dumped direct and receives little further manipulation. When variation from the average is considered, however, the tests show an average variation of about 20 per cent at the edges and but about 5 per cent in the center. (R. W. CRUM.)

(217) "Chart Presentation of Elements Affecting Concrete Construction," by C. S. Pope, *California Highways*, Vol. 3, March. 1926, p. 6.

Effect of mix, voids in coarse aggregate, amount of mixing water, time of curing, etc., on strength of concrete at 28 days. (A. A. LEVISON.)

These charts are concerned principally with factors of design of concrete mixtures and do not include effects of measuring, mixing or placing. (R. W. CRUM.)

(218) "Inundation System for Constant Concrete," *Municipal Improvements*, Vol. 5, February, 1926, p. 15.

A discussion of the bulking action of sand and its relation to concrete, also the importance of water control and the desirability for uniformity in concrete as promoted by use of the Inundation System. (A. A. LEVISON.)

(219) "Mixed Concrete as a Commercial Product," *Buildings*, Vol. 65, March 24, 1926, p. 99.

(220) "Report of Maryland State Highway Commission," *American Highways*, Vol. 5, July, 1926, p. 13.

Concrete hauled 3 miles stronger than concrete not hauled. Concrete hauled 4 miles shows decrease in strength.

(221) "Profitable Central Mixing Plant," by H. A. Sawyer, *Concrete*, Vol. 28 June, 1926, p. 21.

Equipment used in central mixing plant in Texas; special truck bodies, handling bulk cement.

(222) "Central Mixing Plants for Memphis," *Successful Methods*, July, 1926, p. 20.

(223) "Large Mixing Plant Tried Out on Road Work," by R. T. Giles, *Engineering News-Record*, Vol. 97, November 25, 1926, p. 866.

(224) "Commercial Mixed Concrete and Dry Batch Plants," by J. Montgomery, *Engineering News-Record*, Vol. 96, April 15, 1926, p. 618.

(225) "Mixed Concrete as Commercial Product," *Engineering and Contracting*, Vol. 65, March 24, 1926, p. 99.

(226) "Ready Mixed Concrete Easily Sold in Birmingham, Ala.," by W. E. Barker, *Engineering News-Record*, Vol. 96, February 18, 1926, p. 282.

Blast furnace slag aggregate.

(227) "Studies on Duration of Set and Remixing of Concrete," by R. Feret, *Revue Matériels de Construction et Travaux Publics*, No. 203, p. 237 (1926).

Concrete mixtures of 7 and 9 per cent water remixed 1½, 5 and 8 hours after mixing.

(228) "Prehydration of Cement in New Method of Concrete Mixing," by W. B. Jones, *Engineering News-Record*, Vol. 96, May 27, 1926, p. 850.

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(229) "Cement Requirements for Some Concrete Mixes," by Harold Allen, *Concrete*, November, 1927, p. 13.

(230) "Cement Requirements for Some Concrete Mixes," by A. D. Conrow and Harold Allen, *Transactions*, Kansas Engr. Soc., p. 12-21.

(231) "Water-Cement Ratio and Concrete Mix," by F. R. McMillan, *Canadian Engineer*, Vol. 52, June 7, 1927, p. 574.

Importance of the quantity of mixing water.

(232) "Density of Concrete and the Water-Cement Ratio," by F. R. McMillan, *Engineering News-Record*, Vol. 98, March 17, 1927, p. 445.

Showing that cement paste governs concrete density, and density is function of water content.

(233) "Design of a Water-Cement Ratio Concrete Mixture," by R. P. V. Marquardsen, *Roads and Streets*, Vol. 67, July, 1927, p. 304.

New method for designing water-cement ratio concrete mixtures that is not based on the fineness modulus theory.

(234) "The A B C's of Good Concrete," *Concrete*, Vol. 31, August, 1927, p. 29.

Amount of mixing water most important; slung test; how to get concrete of predetermined strength.

(235) "Determination on the Job of the Quantity of Mixing Water for Concrete," by Bolomey, *Le Ciment*, Vol. 32, November, 1927, p. 418.

(236) "New Methods of Making Concrete," by Magnel, *Le Genie Civil*, Vol. 9, No. 8, 1927.

(237) "Water Ratio Specification for Concrete and Its Limitations," by A. T. Goldbeck, *Bulletin 3*, Nat. Crushed Stone Assn., August, 1927.

(238) "Water Ratio Specifications for Concrete," by L. A. Perry, *Proceedings*, Am. Soc. Civil Engrs., January, 1927, p. 99, December, 1926, p. 2030.

Discussion of paper by F. R. McMillan and Stanton Walker.

(239) "Symposium on Field Control of the Quality of Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part II, pp. 335–436 (1927).

1. "Proportioning of Concrete," by R. W. Crum, A discussion of the factors that affect the strength of concrete, and the methods for design of mixtures. Both water-cement ratio and void-cement ratio are indices of the resultant strength. Concrete mixtures may be designed by either the water-cement ratio method or mortar void method with reasonably concordant results. The paper points out that for accurate results in either case the design should be based on preliminary tests of the materials. A need for accurate water control and the advantages of proportioning by weight.

2. "Mixing of Concrete," by Duff A. Abrams. The paper discusses the mixing of concrete from the point of view of its influence upon quality. The principal classes of mixers are described. Time factor of mixing and modern requirements are quoted from technical specifications.

3. "Conveying and Placing Concrete," by Nelson L. Doe. The paper discusses certain features of conveying and placing concrete and their effect upon the quality of concrete. Also the various operations involved in the distribution of concrete are presented and the strong and weak points discussed.

4. "Construction Joints and Expansion Joints," by R. L. Bertin. This paper defines construction and expansion joints and discusses their effect upon concrete structures.

5. "Insuring Quality Concrete in Cold Weather," by F. H. McGraw. This paper enumerates and describes the measures which may be taken to protect concrete against injury due to low temperatures in cold weather and the conditions under which each of these measures should be applied.

6. "Transverse Tests as a Criterion of the Quality of Concrete," by H. S. Mattimore. Since the modulus of rupture is used as a basis of design for all rigid pavements in highway work, the transverse test is largely replacing the compression test, and all indications are that in the near future it will be the standard method of control for concrete in the highway field.

7. "The Field Testing of Concrete," by R. B. Young. The paper defines testing as "putting to the proof" and discusses at length the object and need of thorough field testing. (A. A. LEVISON.)

(240) "New Terminal Warehouse at Montreal," by J. J. Shea, *Canadian Engineer*, Vol. 53, October 18, 1927, p. 457.

This paper discusses the construction of a combination dry and cold storage terminal warehouse, one of the interesting features of the paper being the method of maintaining an even temperature during winter months.

During the winter months, the concrete was maintained at 70° F. by wrapping all of the outside of the building with tarpaulin and placing one coke salamander to every 200 sq. ft. of floor area. The sand and gravel were heated in bins by use of steam coils and to every batch of concrete there was added a 2 per cent solution of calcium chloride. Steam jets were used on the steel to remove the chill. All sand, stone, cement and steel were tested before going into the job and a slump test was taken twice a day during pouring. (A. A. LEVISON.)

(241) "Field Control of Concrete Making—Study of Late Practice," by R. W. Crum, *Proceedings*, Highway Research Board, Vol. 6, p. 232 (1927).

(242) "Notes on Concrete—Wacker Drive," by A. R. Lord, *Proceedings*, Am. Concrete Inst., Vol. XXIII, p. 28 (1927).

(243) "New Method of Mixing Concrete," *Ferro-Concrete* (London), January, 1927.

U. S. patent provides for mixing concrete in two stages. In first stage cement is mixed with the water, and in the second the grout and ingredients are mixed together. (15 seconds for each mixing.) Prevents balls of unhydrated cement, saves time in mixing and makes economical plant layout. (A. A. LEVISON.)

(244) "Commercial Mixing Plant Turns Out 1,000 Cubic Yards of Concrete Daily," *Concrete*, Vol. 30, April, 1927, p. 33.

Pittsburgh plant sells ready-mixed concrete of any mix in any quantity.

(245) "Ready Mixed Concrete from Birmingham Plant Finds Easy Market," *Engineering News-Record*, Vol. 98, May 12, 1927, p. 776.

Increase to use of 100,000 cu. yd. in 1926.

(246) "Large Central Mixing Plant Used in Los Angeles Street Paving," *Pacific Street and Road Builder*, September, 1927, p. 19.

(247) "A Certified Concrete Mixing System," *Contractors and Engineers Monthly*, Vol. 15, September, 1927, p. 85.

Concrete from mixer mounted on truck has many advantages over concrete hauled from central mixing plant to job.

(248) "New Mixer for Small Jobs," *Contractors and Engineers Monthly*, Vol. 14, June, 1927, p. 132.

Paving mixer may be converted into a building mixer in a few minutes. (A. A. LEVISON.)

(249) "New Mortar and Plastic Mixer," *Engineering and Contracting*, Vol. 66, July, 1927, p. 313.

New mixer brought out by Marsh-Capron Co.

It is stated the machine which is to be known as the "Mechanical Hoeman" will turn out a thoroughly mixed four-hod batch of any kind of mortar or plaster in 2 minutes. It is of the drum type and is powered with a two-cylinder engine. (A. A. LEVISON.)

(250) "A Mixer for Plaster as Well as Cement," *Contractors and Engineers Monthly*, Vol. 15, September, 1927, p. 102.

Thorough mix is obtained and time and material are saved.

(251) "New Truck Concrete Mixer Handles Crushed Stone Aggregates," *Rock Products*, Vol. 30, August 6, 1927, p. 93.

Barrymore concrete mixer is now equipped with a new body-mixer design

(252) "Special Body for Hauling Concrete," *Roads and Streets*, Vol. 67, October, 1927, p. 460.

(253) "Concrete Mixer Mounted on Truck Does Mixing in Transit," *Engineering News-Record*, Vol. 98, March 24, 1927, p. 497.

Transit mixer makes it possible to sell concrete beyond distance which would be possible with ready mixed concrete.

(254) "Apparatus for Curing Concrete," by L. D. Barrows, *Canadian Engineer*, Vol. 52, May 24, 1927, p. 543.

This is a description of apparatus for adding definite changes to calcium chloride to batches of concrete. The solution of calcium chloride is mixed in two barrels alternately. A pump actuated by the mixer mechanism, running continuously transfers the solution to a gravity measuring tank. A three way valve on a three branch pipe line connecting mixing barrels, measuring tank and mixer drum is actuated by the skip so that the correct amount of solution is added to each batch, and so that the flow in the pipe line is by-passed around the measuring tank while it is being discharged. (Note.—This is a common type of equipment for the purpose.) (R. W. CRUM.)

(255) "An Improved One-Bag Concrete Mixer," *Contractors and Engineers Monthly*, Vol. 14, June, 1927, p. 132.

Mixer designed for speed, convenience, durability and compactness. (A. A. LEVISON.)

(256) "Continuous Manufacture of Concrete with Dry Mixture," *Le Ciment*, Vol. 32, January, 1927, p. 26.

Manufacture of large quantities of concrete without interruption, which can be used immediately.

(257) "Mixing of Concrete," by D. A. Abrams, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part II, p. 361 (1927).

Mixing of concrete from the point of view of its influence upon the quality.

(258) "Retempering Concrete," *Concrete and Construction Engineering*, Vol. 22, August, 1927, p. 466.

Need for experimental work.

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(259) *Concrete*, p. 101 (C. M. S.), September, 1928.

Preparation of the raw mix by the dry method. Uniformity of raw mix ideal condition of the raw mix effect on burning—what is a homogeneous mix?

Correcting the mix: wets *versus* dry. How to blend with the dry method, by Marc Elber.

(260) "Effect of the Length of the Mixing Period on the Quality of the Concrete Mixed in Standard Pavers," by J. L. Harrison, *Public Roads*, July, 1928, p .93.

(261) "Practical Application of the Water-Cement Ratio Method of Controlling Concrete," by W. E. Hart, *Concrete*, Vol. 32, June, 1928, p. 37.

Strength specifications demonstrated as practical; how to write a specification incorporating the water-cement ratio control method; revising building code requirements; economy of controlled concrete.

(262) "Amount of Mixing Water for Concrete of Normal Consistency," by H. Luftschitz, *Zement*, Vol. 17, March 15, 1928, p. 443.

(263) "Specifications of Concrete Mixes," by D. A. Abrams, *Le Ciment*, Vol. 33, January, 1928, p. 2.

(264) "Concrete Production Control," by J. A. Kitts, *Concrete*, Vol. 32, May, 1928, p. 13.

Thorough control of concrete production includes constant laboratory control and research tests on the job and at the aggregate plant in coordination with the mixing, placing and curing inspection and the testing and proof of cement before delivered on the job, and at such times as may be necessary to detect deterioration.

The essential control measures are:

1. Specifications.
2. Adequate testing laboratories.
3. Aggregate tests.
4. Mixed aggregate tests, including cement water.
5. Mortar and concrete proportioning.
6. Recalculation and change of proportions.
7. Coordination of laboratory and field.
8. Thorough field inspection of measuring, quantities, etc.
9. Slump tests.
10. Maintenance of accurate records. (A. A. LEVISON.)

(265) "Water Ratio in (German) Standard Cement Mixes," by H. Luftschitz, *Zement*, Vol. 17, p. 443 (1928).

(266) "Sand Grading, Water-Cement Ratio, and Practical Concreting," by G. P. Manning, *Concrete and Constructing Engineers*, Vol. 23, October, 1928, p. 643.

A criticism of the American method of presenting results of experiments on sand grading.

(267) "Quality of Cement in Concrete Mixes Specified in Volume Ratios," by J. Luhrs, *Barring*, Vol. 9, p. 564 (1928).

Table is given showing the differences in strengths of 1:5 and 1:8 mixes resulting from cements of different specific gravities. Desire to reduce cost tends toward use of lighter cement and consequent reduction in strength, against which no protection is afforded by specification.

(268) "Selling Concrete Over the Counter," *Concrete*, Vol. 32, March, 1928, p. 41.

(269) "Developing a Ready-Mixed Concrete Business," by E. N. Jones, *Engineering News-Record*, Vol. 101, August 9, 1928, p. 1926.

Correcting segregation in concrete delivery; insuring designed concrete.

(270) "Supplying Philadelphia's Demand for Ready-Mixed Concrete," *Rock Products*, Vol. 31, July 7, 1928, p. 100.

(271) "Relation between Strength and Length of Haul of Concrete Mixed at a Central Mixing Plant," *Public Roads*, Vol. 9, September, 1928, p. 151.

(272) "Pumping Bulk Cement in a Ready-Mixed Concrete Plant," Golden Gate Atlas Materials Co., San Francisco, Calif., *Rock Products*, Vol. 31, No. 22, October 27, 1928, p. 105.

(273) "Central Mixing Plant for Paving," *Canadian Engineer*, Vol. 54, February 14, 1928, p. 217.

Details of method.

(274) "Ready-Mixed Concrete Proves Economical on Birmingham Road Project," by C. J. Rogers, *Concrete Highways and Public Improvements*, Vol. 12, September, 1928, p. 200.

(275) "De-aerated Concrete," *Canadian Engineer*, Vol. 54, January 10, 1928, p. 134.

Mixing is done in a vacuum. In a 1:2:4 mix, made in the usual way, the concrete weighed 140 lb. per cu. ft. while by mixing the same materials by the de-aerated method, the weight was increased to 148 lb. per cu. ft.

Compressive strength is increased by the increased density and the concrete is more waterproof. Most engineers will feel that the process has a limited application and will hesitate to believe that any advantage gained by mixing in this manner may not be entirely disseminated if the placing of the concrete is by belts or chutes, or if the mixture is transported any distance. (A. A. LEVISON.)

(276) "Portable Mixer Used in Remodelled Products Plant," *Concrete*, Vol. 33, August, 1928, p. 20.

Portable mixer permits accurate proportioning; ingenious device for controlling water content. (A. A. LEVISON.)

APPENDIX X

BAND TYPE CIRCUMFERENTIAL EXTENSOMETER FOR POISSON'S RATIO DETERMINATIONS

By C. H. Scholer[1]

The instrument briefly described herein was developed in the Applied Mechanics Laboratory of the Kansas State Agricultural College. In its present form it is not free from objections but it is felt that the type has real possibilities and that it is worth while to bring it to the attention of others.

It consists of a band of spring steel $\frac{3}{4}$ in. in width and 0.018 in. in thickness which encircles the cylinder and is held in place by a coiled spring as shown in Figs. 1 and 2. The encircling band has attached to each of its ends, a steel block to which the holding spring is attached and in which is located the gage point to receive the prong of a Whittemore strain gage. One of these blocks is adjustable to take care of minor variations in the circumference of the specimens tested.

It is important in using this instrument that the cylindrical specimens be accurately formed and that complete contact is reached throughout the entire circumference of the cylinder before the strain gage is set so that any change in circumference will be immediately registered. The tension in the spring should be just sufficient to insure this close contact. It has been found that rubbing the surface of the cylinder with graphite before attaching the extensometer facilitates placing the band in position and securing proper adjustment.

This type of instrument will give an automatic average of the change in diameter of the specimen under load. The change in circumference is read directly, only a slight correction factor being necessary to correct for the fact that the gage points are not in contact with the surface of the cylinders.

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[1] **Professor of Applied Mechanics and Engineer of Tests, Kansas State Agricultural College, Road Materials Laboratory, Manhattan, Kansas.**

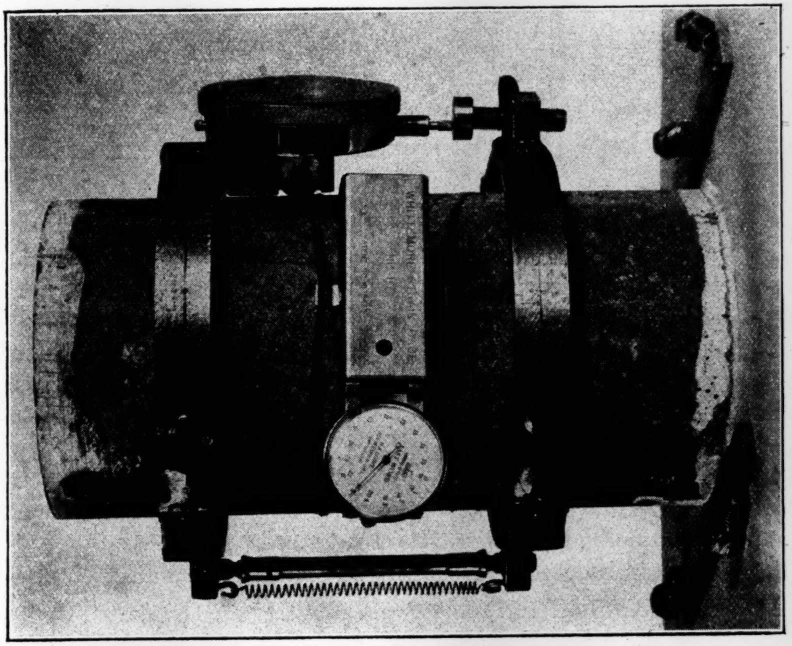

FIG. 2.—Band Type Circumferential Extensometer for Poisson's Ratio Determination Showing Strain Gage in Place.

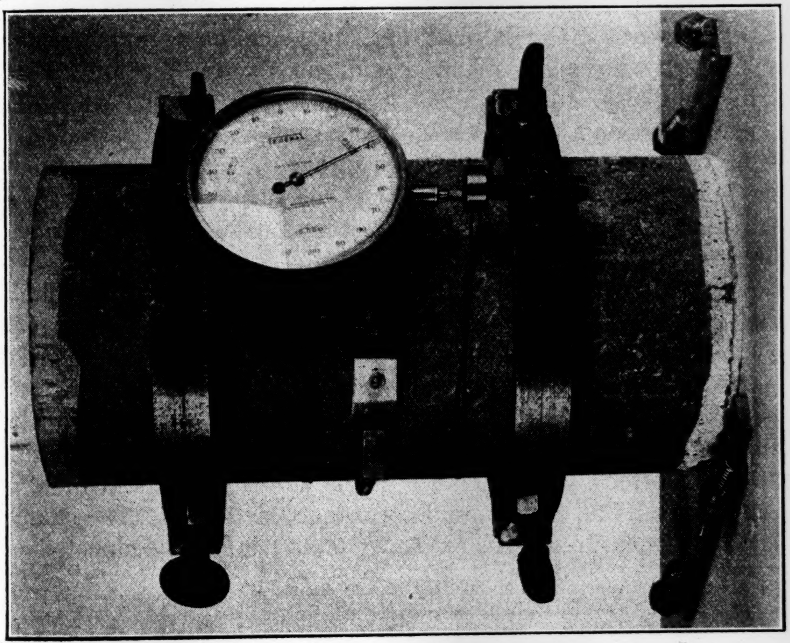

FIG. 1.—Band Type Circumferential Extensometer for Poisson's Ratio Determinations.

DISCUSSION

MR. H. J. GILKEY[1] (*by letter*).—More than two years ago, Mr. Fredrik Vogt[2] and the writer developed a simple form of lateral extensometer suitable for use on concrete specimens. Extensions are measured on a diameter and are read on a 0.0001-in. "last word" dial to 0.00005 in., since there is a hinge at the back. The instrument was made in two parts in order to thread it through the type of compressometer already in use. The compressometer resembles that described by Walker.[3] At the University of Colorado this type of compressometer has been very successfully adapted to both 3 by 6-in. and 2 by 4-in. compressive cylinders, in addition to use with 6 by 12-in. cylinders as in other laboratories.

Lateral extensometers were also made for the smaller sizes of specimens and have been very satisfactory for all three sizes.

Figure 1 shows the way in which the extensometers themselves are made and attached; Fig. 2 shows the three sizes of specimens with both compressometer and extensometer attached and spacing bars down as when a test is performed. A semi-autographic record can be made by having a drum which turns in proportion to the travel of the poise, on which the operators who watch each dial make cross-marks on a straight line as each dial division is passed.

From the hundreds of tests performed with the diametral extensometer and apparently from the tests of others who have used mirror extensometers for measuring diametral strains, there seems to be no reason to suspect that the strain along any one diameter is not representative of what occurs along others. Nevertheless this should be verified experimentally. Moreover the strains at best are small in the lower ranges of stress and a gage line three times as long has obvious advantages.

During the past year the writer has devoted some attention to the same problem but the results thus far have been less encouraging than those reported by Mr. Scholer. The writer used a stiff band of spring steel which had three rounded contacts at 120 deg. The change in length was measured with an Ames 0.0001-in. dial connected on the tangential prolongation of the spring. It is apparent that the rounded contacts must slide on the specimen as it expands in girth. The dial failed to register any change at low loads. This type of instrument might work with three roller or three rocker contacts reasonably free from friction and slack.

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[1] Professor of Civil Engineering, University of Colorado, Boulder, Colo.

[2] Docert, Norges Teknishe Hoiskole, Trondhjem, Norway.

[3] Stanton Walker, "Modulus of Elasticity of Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. XIX, Part II, p. 510 (1919).

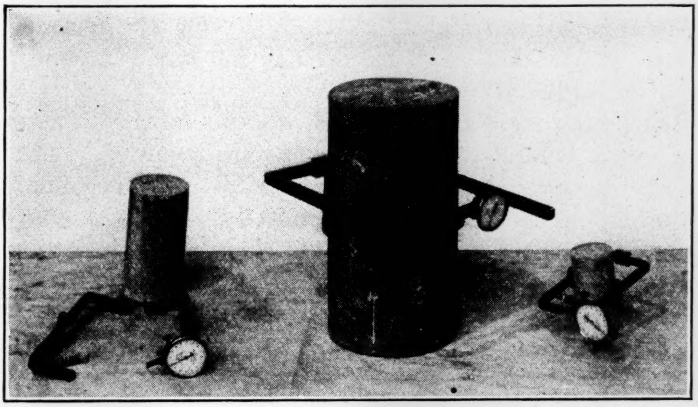

FIG. 1.—Showing Extensometer and Means of Attachment.

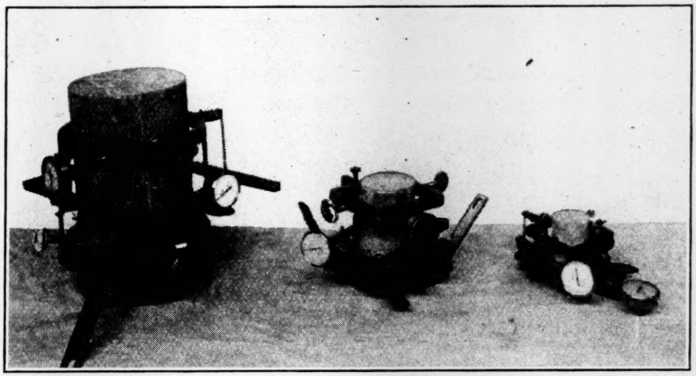

FIG. 2.—Showing Several Sizes of Specimens with Extensometer and Compressometer Attached.

Another possibility that the writer had considered was a very flexible band (like a piece of light steel tape) that would fit the specimen very perfectly and the ends of which would terminate into an aluminum block carrying an Ames or other suitable dial. The initial tension would have to be enough to support the unbalanced weight of block and dial. It might be possible to have an independent support for this weight since all that is desired is a differential measurement in the loop that encircles the specimen.

In use, any of these devices, except a three or six-point roller or rocker connection, must slide with respect to the concrete as the specimen expands. This introduces a frictional problem which the graphite used by Mr. Scholer probably helped to relieve. Whether mere lubrication is enough is questionable. Another respect in which Mr. Scholer's instrument might be improved, in the writers estimation, is to reduce the spiraling effect by having the two ends pass adjacent to one another or by having one end narrowed and passing through a slot in the other.

Perhaps other members have been working on the same problem. It might prove helpful if their findings were recorded. The writer is especially desirous of knowing whether Mr. Scholer's instrument, or any others, seem to register accurately for low loads on the specimen. The writer wonders if initial sluggishness in lateral-strain measuring devices may not account for some of the lower values that have been reported for Poisson's ratio (see Table I, Appendix XII for examples).[1]

MR. C. H. SCHOLER[2] (*author's closure by letter*).—Since the preparation of the report it has come to the author's attention that the Aluminum Company of America has used a similar type of instrument within the last two years with reasonable success. It is the author's understanding that in this work a strip of light aluminum foil was wrapped around the specimen before the band was attached.

Referring to Mr. Gilkey's discussion, the author has had considerable difficulty in being sure of getting readings at low unit stresses; at times the deformations were apparently accurately recorded from the start, while again, deformations were not promptly indicated. The matter of adjustment to the specimen and lubrication between band and specimen requires further development.

The spiralling effect mentioned by Mr. Gilkey has been taken care of in the instrument by passing one end through a slot in the other. This detail does not show in the pictures.

Some two years ago the author inspected the lateral extensometers which Mr. Gilkey and Mr. Vogt had developed. Similar instruments have been built in the author's laboratory and used with very satisfactory results which give very close checks as compared with the circumferential extensometer.

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[1] See p. 666.

[2] Professor of Applied Mechanics and Engineer of Tests, Kansas State Agricultural College, Road Materials Laboratory, Manhattan, Kans.

APPENDIX XI

DIGEST OF TESTS IN THE UNITED STATES FOR THE DETERMINATION OF THE MODULUS OF ELASTICITY OF PORTLAND CEMENT MORTAR AND CONCRETE

By L. W. Teller[1]

1895 to 1899

(1) Falk, M. S., "Note on the Coefficient of Elasticity of Concrete and Mortar Beams During Flexure," *Transactions*, Am. Soc. Civil Engrs., Vol. 50, p. 473 (1903).

The beams were made in 1895 and tested at Columbia University in 1902. There were four specimens in the test, two of gravel concrete and two of mortar. The sand was sharp and clean and gravel was washed. The tests were made in an Emery testing machine, deflections being measured by a lever deflectometer read with a vernier to 0.001 in.

The difference between the deflection for a given load and the permanent set for that load was taken as the elastic deformation and the modulus of elasticity was computed from this elastic deformation. Deflection curves are given.

The modulus of elasticity values given vary from 387,000 lb. per sq. in. for an extreme fiber stress of 229 lb. per sq. in. to 2,440,000 lb. per sq. in. for an extreme fiber stress of 636 lb. per sq. in.

There appears to be no distinct difference between the values for mortar and those for concrete.

Tests are reported in a discussion by E. J. McCaustland, made at Cornell University. There were about 30 specimens (beams and columns) included in the tests and these were made in 1902 by students. The mixes used were 1:2:3, 1:3:4, 1:3:5 and 1:2:5 in the columns and the water varied between 23 and 31.8 per cent. The sand had a uniformity coefficient of 1.84 by Hazen's method. Sandstone was used for the coarse aggregate and a standard grade of portland cement was employed.

There were 7 beams each 2 by 2¾ by 28 in. and 19 columns each 10 in. in diameter and 40 in. long.

The modulus of elasticity of the beams was determined by measuring the deflection with a micrometer reading to 0.0001 in. The values obtained varied between 1,582,000 and 460,000 lb. per sq. in. at stresses of from 190 to 618 lb. per sq. in.

The columns were tested in a 400,000-lb. compression machine, the deformation being determined with micrometers which measured the distance between yokes held to the column by set screws, these being rods on opposite sides of the column. Contact was determined electrically with a bell. No further details are given as to apparatus.

Stress-strain curves are given for the four mixes used. The modulus of elasticity found by the column tests ranged from 840,000 to 3,060,000 lb. per sq. in., the majority of the values being approximately 1,300,000 lb. per sq. in.

(2) Reid, Homer A., "Concrete and Reinforced Concrete Construction." (Abstract of Rafter's tests recorded in the annual report of the State Engineers of New York, 1897.) Pub. by McClark Pub. Co.

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[1] **Senior Engineer of Tests, U. S. Bureau of Public Roads, Washington, D. C.**

Compression tests were made on 544 12-in. cubes tested at an average age of 600 days. No details are given as to materials except that portland cement was used. The mixes were 1:1:4, 1:1:5, 1:2:6 and 1:2:7, made up in each of three consistencies, dry, medium and wet.

Approximate Proportions	Consistency	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.		
			At 100 to 600 lb. per sq. in.	At 100 to 1000 lb. per sq. in.	At 1000 to 2000 lb. per sq. in.
1:1:5	Dry	4659	3 571 000	2 812 000	1 667 000
1:1:4	Plastic	4462	4 167 000	2 500 000	1 219 000
1:2:6	Dry	3686	2 083 000	1 875 000	1 111 000
1:2:6	Dry	4000	3 125 000	3 000 000	2 000 000
1:2:6	Dry	2598	3 125 000	2 812 000	1 398 000
1:2:6	Plastic	2400	2 500 000	2 143 000	1 163 000
1:2:6	Plastic	3600	3 571 000	3 000 000	2 000 000
1:2:6	Plastic	3400	3 125 000	2 812 000	1 667 000
1:2:6	Excess	2950	2 500 000	2 045 000	1 163 000
1:2:6	Excess	3436	3 125 000	2 812 000	1 471 000
1:2:7	Dry	2800	3 125 000	2 812 000	1 724 000
1:2:7	Dry	3283	2 500 000	2 368 000	1 282 000
1:2:7	Plastic	3132	2 778 000	2 250 000	1 429 000
1:2:7	Excess	3400	3 571 000	2 647 000	1 250 000

(3) Burr, W. H., "The Elasticity and Resistance of the Materials of Engineering," from "Tests of Metals and Other Materials," Watertown Arsenal, 1899. Pub. by John Wiley & Sons, Inc., 7th Ed. p. 396 (1915).

Table 1 gives the coefficient of elasticity for concrete of 1:2:4, 1:3:6 and 1:6:12 mixes between the loads of 100 to 600, 100 to 1000 and 1000 to 2000 lb. per sq. in. The ages ranged between 7 days and 6 months. For 1:2:4 concrete under loads between 100 and 600 lb. per sq. in. the values range from 2,592,000 at 7 days to 3,646,000 at 6 months.

Table VI gives the results of a few tests on 12-in. cubes of cinder concrete tested at the age of 90 days. For a 1:1:3 mix the crushing strength was 2420 lb. per sq. in. (average) and the average modulus of elasticity was 2,810,000 lb. per sq. in. For a 1:2:5 mix the average crushing strength was 1300 lb. per sq. in. (average) and the average modulus of elasticity was 1,068,000 lb. per sq. in.

(4) "Tests of Concrete Cubes from Boston Elevated Railway," from "Tests of Metals and Other Materials," Watertown Arsenal, 1899, p. 717.

Aggregates.—Sand: coarse, clean and sharp. Voids measured loose, 33 per cent. Stone: conglomerate from Roxbury, Mass. Voids measured loose, 49.5 per cent, maximum size, 2½ in.

MIXES	PER CENT WATER $\left(\frac{\text{WT. WATER}}{\text{WT. CEMENT}}\right)$
1:0:2	20.9
1:2:4	30.3
1:3:6	39.3
1:6:12	71.1

Cement.—Saylor's Portland, Atlas brand, Alpha Portland, Germania Portland, and Alsen's Portland.

The test specimens were 12-in. cubes made at temperatures of 22 to 40° F. and cured at temperatures from 32 to 50° F.

No description is given of apparatus or of method of testing except that a 5-in. gage length was used and deformations were read to 0.0001 in. Some of the values determined in these tests are given in the following table:

Cement	Proportions	Age, months	Modulus of Elasticity, lb. per sq. in.		Compressive Strength, lb. per sq. in.
			At 100 to 600 lb. per sq. in.	At 100 to 1000 lb. per sq. in.	
Saylor's	1:2:4	1	2 500 000	2 500 000	2119
		3	3 571 000	3 461 000	2778
		6	5 000 000	4 500 000	3959
	1:3:6	1	2 778 000	3 214 000	2600
		3	4 167 000	3 750 000	2805
		6	2 500 000	2 812 000	3743
Atlas	1:2:4	1	3 125 000	2 812 000	2373
		3	4 167 000	3 214 000	2918
		6	3 125 000	3 214 000	4000
	1:3:6	1	3 125 000	2 647 000	2097
		3	2 778 000	2 500 000	2800
		6	3 571 000	3 461 000	3256

Other tests of concrete were made at Watertown Arsenal. Again the specimens were 12-in. cubes and the gage length 5 in. The coarse aggregate was trap rock of various maximum sizes. Some of the values determined in these tests are given in the following table:

Cement	Composition		Age, months	Modulus of Elasticity, lb. per sq. in.		Compressive Strength, lb. per sq. in.
	Proportions	Maximum Size Coarse Aggregate, in.		At 100 to 600 lb. per sq. in.	At 100 to 1000 lb. per sq. in.	
Alpha Portland	1:2:2	$2\frac{1}{2}$	4	3 125 000	2 812 000	2600
	1:2:3	$2\frac{1}{2}$	4	3 125 000	2 812 000	2400
	1:2:4	$2\frac{1}{2}$	4	2 500 000	2 250 000	2241
	1:2:5	$2\frac{1}{2}$	4	3 571 000	2 500 000	2542
	1:2:6	$2\frac{1}{2}$	4	3 125 000	3 000 000	2314
	1:2:4	$2\frac{1}{2}$	4	2 778 000	1 389 000	2334
	1:3:6	$2\frac{1}{2}$	4	3 125 000	2 368 000	1932
	1:2:4	$\frac{5}{8}$	4	2 778 000	2 647 000	2600
	1:3:6	$\frac{5}{8}$	4	2 273 000	1 800 000	1502
	1:2:2	$\frac{5}{8}$	3	2 778 000	2 647 000	2364
	1:2:3	$\frac{5}{8}$	3	3 125 000	2 647 000	2152
	1:2:5	$\frac{5}{8}$	3	2 273 000	2 045 000	1828
	1:2:6	$\frac{5}{8}$	3	2 083 000	1 667 000	1853
	1:2:2	$1\frac{1}{2}$	3	2 778 000	2 812 000	1823
	1:2:3	$1\frac{1}{2}$	3	2 778 000	2 500 000	2009
	1:2:4	$1\frac{1}{2}$	3	2 778 000	2 368 000	2199
	1:2:5	$1\frac{1}{2}$	3	2 273 000	2 368 000	2696
	1:2:6	$1\frac{1}{2}$	3	2 273 000	1 800 000	2539

1902

(5) Hatt, W. K., "Tests on Reinforced Concrete Beams," *Proceedings*, Am. Soc. Testing Mats., Vol. II, p. 161 (1902).

These tests include the determination (in a few tests) of the modulus of elasticity of concrete in both tension and compression, the tension specimens being of the general form of an eye-bar, the compression specimens being 8 by 12-in. cylinders.

The apparatus used for measuring deformation consisted of hook micrometers attached to one circumferential steel ring and having contact with another ring a definite distance from the first. In the case of the tension specimens this gage length was 17.5 in.; in the compression specimens 6.5 in. The contact was indicated electrically and the micrometers were read directly to 0.001 in. and estimated to one-tenth of this value.

The materials used included limestone (crusher run), coarse gravel of good quality, clean sharp pit sand and bituminous coal cinders (about 50 per cent of which was fine ash).

The data concerning plain concrete are given as follows:

Coarse Aggregate	Proportions	Age, days	Modulus of Elasticity, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Stress, lb. per sq. in.	Compressive Strength, lb. per sq. in.
TENSION TESTS						
Limestone	1:2:4	35	2 700 000	300	....	....
	1:2:4	33	2 400 000	305	....	....
	1:2:4	28	1 400 000	260	....	....
	1:2:4	26	1 900 000	280	....	....
COMPRESSION TESTS						
Limestone	1:2:4	9	4 702 000	...	750	2880
			3 940 000	...	1500	....
	1:2:4	14	4 340 000	...	750	2575
			3 680 000	...	1500	....
Cinder	1:2:4	9	558 600	...	....	495
	1:2:4	9	553 000	...	....	595
	1:2:4	7	630 000	...	....	416
Gravel	1:5	6	2 088 000	...	....	1185

1903

(6) "Tests of Twelve-inch Concrete Cubes at Watertown Arsenal," from "Tests of Metals and Other Materials," Watertown Arsenal, 1903, p. 536.

Materials.—Lehigh portland cement and cinders.

Specimens cured in air.

Deformations were measured to 0.0001 in. by apparatus which is not described.

Data Obtained:

Composition		Age, days	Modulus of Elasticity at Stress of 500 to 1000 lb. per sq. in.	Set at Stress of 500 lb. per sq. in.,[a] in.	Compressive Strength, lb. per sq. in.
Mix	Water per Sack of Cement, cu. ft.				
1:2:4	$1\frac{1}{3}$	38	1 786 000	0	1950
1:2:4	$1\frac{1}{3}$	38	1 923 000	0	2050
1:2:4	$1\frac{1}{3}$	224	1 471 000	0	2600
1:2:4	$1\frac{1}{3}$	224	1 563 000	0	2500
1:$2\frac{1}{2}$:5	$1\frac{2}{3}$	38	1 250 000	0.0001	1400
1:$2\frac{1}{2}$:5	$1\frac{2}{3}$	38	893 000	0.0005	1400
1:$2\frac{1}{2}$:5	$1\frac{2}{3}$	224	1 136 000	0 0002	1980
1:$2\frac{1}{2}$:5	$1\frac{2}{3}$	224	1 250 000	0.0001	2020
1:3:6	2	34	781 000	0.0001	1200
1:3:6	2	34	1 000 000	0.0005	1330
1:3:6	2	220	1 000 000	0.0002	1730
1:3:6	2	220	735 000	0.0008	1560

[a] In a 5-in. gage length.

1904

(7) "Elastic Properties and Compressive Strength of Concrete Prisms," from "Tests of Metals and Other Materials," Watertown Arsenal, 1904, p. 309.

Materials.—Vulcanite cement; fine aggregate not described; coarse aggregate, trap rock, gravel or cinders.

Specimens were 6 by 4 by 24-in. prisms.

Apparatus not described; 12-in. gage length used and deformations were measured to 0.0001 in.

The proportions, water-cement ratio and strength data are given in the following table:

Composition		Water, per cent	Age at Test, days	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.	
Proportions	Coarse Aggregate				At 100 to 500 lb. per sq. in.	At 500 to 1000 lb. per sq. in.
1:1:2.......	½-in. trap rock.	40.0	173	4560	....	3 529 000
1:1:2.......		29.2	173	4180	....	5 000 000
1:2:3.......		45.0	173	3700	....	4 615 000
1:2:4.......		42.9	175	1480	....	2 500 000
1:3:6.......		40.0	168	1410	....	1 667 000
1:1:2.......	2½-in. trap rock	29.2	171	2200	....	4 615 000
1:2:3.......		37.5	175	1680	....	3 529 000
1:2:4.......		42.9	175	1210	....	2 400 000
1:3:6.......		50.0	171	790	2 824 000	....
1:1:2.......	cinders........	29.2	171	2200	....	2 400 000
1:2:3.......		43.8	171	1400	....	1 429 000
1:2:4.......		57.1	171	800	1 412 000	....
1:3:6.......		80.0	170	740	1 091 000	....
1:1:2.......	⅜-in. gravel....	33.3	170	2600	....	2 727 000
1:2:3.......		37.5	170	2060	....	2 857 000
1:2:4.......		42.9	171	1700	....	2 308 000
1:3:6.......		80.0	169	580	1 200 000	....

A permanent set of 0.0001 to 0.0050 in. in a 12-in. gage length was found at a stress of 500 lb. per sq. in.

1905

(8) Woolson, I. H., "Investigation of the Effect of Heat upon the Crushing Strength and Elastic Properties of Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. V, p. 335 (1905).

This work was done in connection with the Bureau of Building, New York City.

Materials.—Coarse aggregates, limestone and cinders; cement, a blend of several brands.

Mixes.—1:2:4 and 1:2:5.

The object of the tests was to determine the effect of previous heating to high temperatures, such as are encountered in fires, on the crushing strength and modulus of elasticity of concrete; also to find at what heat these properties start to change.

The concrete was subjected to heat ranging from 500 to 2250° F. and tested at time intervals up to three weeks after heating.

Compression tests were made on 4-in. cubes and the elastic properties were measured on prisms 6 by 6 by 14 in. in size, using a 12-in. gage length. A 100,000 lb. testing machine was used.

An electric contact extensometer was fastened to the specimens by clamps.

The results indicate a very striking decrease in the crushing strength and in the modulus of elasticity when concrete is subjected to high temperatures.

The crushing strength for unheated specimens was 1820 lb. per sq. in., while heating to 1500° F. 9 days before testing caused the crushing strength to drop to 250 lb. per sq. in.

The modulus of elasticity, under the same conditions, dropped from 3,180,000 lb. per sq. in. for the unheated concrete to 19,400 lb. per sq. in. for that which had been heated.

1906

(9) Thompson, S. E., "The Consistency of Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. VI, p. 358 (1906).

These tests were made at the Watertown Arsenal and at the Massachusetts Institute of Technology.

Materials.—Atlas Portland cement; sand, Newburyport, specific gravity, 2.65; stone, trap, specific gravity, 2.78.

Mix.—1:2.3:4.6 by weight.

Consistency:

Dry, 5.0 per cent water (based on weight of cement + sand)
Medium, 6.5 per cent water (based on weight of cement + stone)
Very wet, 9.8 per cent water (based on weight of cement + stone)

Size of specimens.—12-in. cubes.

Age at time of test.—1, 2, 6 and 17 months averaged for each consistency.

Average values of the modulus of elasticity:

Dry mix, 4,450,000 lb. per sq. in.
Medium mix, 4,200,000 lb. per sq. in.
Very wet mix, 3,000,000 lb. per sq. in.

(10) Woolson, I. H., "Investigation of the Thermal Conductivity of Concrete and the Effect of Heat upon Its Strength and Elastic Properties," *Proceedings*, Am. Soc. Testing Mats., Vol. VI, p. 433 (1906).

The conclusion is drawn that when concrete is heated to 1500° F. its strength and elastic properties are largely dissipated but author recognizes fact that tests are very incomplete. See also abstract of 1905 tests.

(11) Tests Made at Columbia University Under the Direction of Prof. Wm. H. Burr, *Engineering Record*, Vol. 54, No. 23, Dec. 8, 1906, p. 643.

Concrete of a 1:2½:5 mix was used. The coarse aggregate was crushed limestone and water-cement ratios of 0.25 to 0.31 were employed.

A total of 40 specimens were tested at ages of from 112 to 146 days, 23 compression tests and 17 tension tests.

Extensometer of the electric sounder type was used on a 12-in. gage length.

The average modulus of elasticity found was as follows:

In compression, 2,764,000 lb. per sq. in.
In tension, 2,670,000 lb. per sq. in.

(12) Withey, M. O., "Tests on Plain and Reinforced Concrete," *Bulletin No. 175*, University of Wisconsin.

There are a few auxiliary tests for modulus of elasticity. They were made on 6 by 18-in. concrete cylinders.

Materials.—Coarse aggregate, crushed limestone from Kankakee, Ill.; 48.5 per cent voids; maximum size 1 in.; fine aggregate, sand from local market; 38 per cent voids. "It was too fine to give best results." Cement, blend of five brands of portland cement.

Proportions.—1:2:4 with 8.5 per cent of water.

Apparatus.—Compressometer consisted of two collars attached to the specimen 12 in. apart. A No. 32 copper wire attached to the upper collar and dropped to a system of pulleys on the lower collar where it was transferred to the opposite side, running through a pulley and up to a drum of a dial fastened to the upper collar. The wire was kept under a constant tension by a small weight. The dial drum was 1 in. in circumference and a vernier made possible reading to 0.0001 in. (total deformation).

The modulus values at different stresses are tabulated together with the ultimate strength of the concrete. The average strength of the concrete was 1750 lb. per sq. in. at 28 days and the modulus of elasticity at this time was found to be 2,560,000 lb. per sq. in. It was also included that "In nearly all cases the curve is practically a straight line up to a stress of 400 lb. per square inch."

(13) Talbot, A. N., "Tests of Concrete and Reinforced Concrete Columns," *Bulletin No. 10,* University of Illinois.

Materials.—Coarse aggregate, crushed limestone from Kankakee, Ill., 1 in. maximum size; 54 per cent voids; fine aggregate, good quality sand from Attica, Ind., 28 per cent voids.

Proportions.—1:2:3¾ by loose volume.

Consistency.—"Fairly wet."

Specimens.—(*a*) Seventeen 12-in. cubes; (*b*) nine 8 by 16-in. cylinders; (*c*) columns 9 by 9 in. and 12 by 12 in., 6, 9 and 12 ft. long. They were cured in the laboratory at a temperature of 60 to 70° F. All tests were made at ages of 64 to 71 days.

The testing machine used was a vertical screw universal machine of 600,000 lb. capacity.

Apparatus.—Extensometers were arranged so as to indicate the deformation in the center of each face of the columns. The yokes were fastened with four contact points. Two yokes at the bottom carried the dials, while two at the top carried the extensometer bars. The gage length was usually 12 in. less than the length of the specimen. The dials read to 0.0001 in.

Table 7 shows the data from tests of plain concrete columns and indicates that the stress strain relation is very close to a parabola. At a stress of 1722 lb. per sq. in. the modulus of elasticity was found to be 3,150,000 lb. per sq. in. and at a stress of 1079 lb. per sq. in. it was 1,490,000, showing quite a constant rate of variation between these values.

Table 8 shows similar data for columns containing vertical steel bars (about 1.39 per cent). At a stress of 1220 lb. per sq. in. the modulus of elasticity was found to be 2,570,000 and at a stress of 1560 it was 1,900,000 lb. per sq. in.

A. N. Talbot shows that in the case of a beam the modulus of elasticity at the extreme fibers is not the same as it is near the neutral axis since the value of the modulus of elasticity varies with the magnitude of the stress.

1907

(14) Fuller, W. B., and Thompson, S. E., "Laws of Proportioning Concrete," *Transactions,* Am. Soc. Civil Engrs., Vol. 59, p. 67 (1907).

This paper reports a few tests made to determine the modulus of elasticity of concrete. The mixes used were 1:9, 1:2.5:6.5, 1:3:6 and 1:2.92:5.88 by weight. Various aggregates were included. The specimens were prisms 6 by 6 by 18 in. in size and were tested at the age of about 140 days.

The tabulated data indicate that:

The modulus of elasticity increases with the maximum size of the coarse aggregate.

The modulus of elasticity increases with the percentage of cement present.

The modulus of elasticity is influenced by the character of the aggregates used.

The values obtained varied from 878,000 to 4,650,000 lb. per sq. in. at stresses of between 500 and 100 lb. per sq. in.

(15) Withey, M. O., "Tests on Plain and Reinforced Concrete," *Bulletin 197,* University of Wisconsin.

A few auxiliary tests to determine the modulus of elasticity of the concrete were made. The same materials were used in this series as in the 1906 series of tests.

The mix was 1:2:4. Tests were made at the age of 28 days. No mention is made of methods of curing.

The compressometer is the same as that described in 1906.

Table 5 gives the compressive strength, modulus of elasticity at one third of the compressive strength, tensile strength and the modulus of rupture of the concrete.

The average values are:

Compressive strength, 1940 lb. per sq. in.
Tensile strength, 189 lb. per sq. in.
Modulus of rupture, 352 lb. per sq. in.
Modulus of elasticity, 3,500,000 lb. per sq. in.

(16) Talbot, A. N., "Tests of Concrete and Reinforced Concrete Columns," *Bulletin No. 20*, University of Illinois.

Materials.—Cement, standard portland; fine aggregate, good quality sand, 28 per cent voids; coarse aggregate, crushed limestone from Kankakee, Ill., 50 per cent voids.

Consistency.—"Fairly wet."

Proportions.—1:1½:3, 1:2:4, 1:3:6, and 1:4:8.

Specimens.—6-in. and 12-in. cubes, 8 by 16-in. cylinders, 12-in. round and 12-in. square columns. About one-half the columns were steel reinforced with mild steel bars (1.08 to 3.20 per cent).

Curing.—Laboratory storage. Forms stripped after 10 days and specimens sprinkled twice daily until tested. Temperature of room 55 to 70° F. The 6-in. cubes and cylinders included were stored in damp sand.

Age at test.—From 56 days to 16 months.

Apparatus.—Same as in the 1906 series (*Bulletin 10*).

Table 9 gives the data from the tests of the plain concrete columns. The 1:2:4 concrete at the age of 65 days showed an average initial modulus of elasticity of 3,040,000 lb. per sq. in. This value had increased slightly to 3,147,000 lb. per sq. in. at the age of 192 days. This table shows that the stress-strain relation is very nearly parabolic. The maximum compressive strength of the concrete at 65 days was 1740 lb. per sq. in. and at 192 days was 2025 lb. per sq. in.

Figure 8 in this report shows the effect which repeated loading has on the deformation produced in concrete. Whereas, repeated applications of a unit load of 500 lb. caused no appreciable increase in the unit deformation, when loads which caused a 1500 lb. unit stress are repeated there were indications of a slight increase in deformation, and when the stress was increased to 2500 lb. per sq. in. the unit deformation increased from 0.0010 for the first application to 0.0016 for the tenth application of the load.

(17) Tests at the Watertown Arsenal by the Ordnance Department, U. S. Army, from "Tests of Metals and Other Materials," Watertown Arsenal, 1907.

Twenty-six plain concrete columns 12 by 12 by 96 in. and three 10.37 in. in diameter and 96 in. long were tested. A 50-in. gage length was used. The specimens were cured in air and were seven and nine months old when tested.

Saylor's cement and trap rock crusher dust were used to make the concrete. The proportions were 1:1, 1:2, 1:3, 1:4, 1:5 and 1:6. The water constituted from 15 to 90 per cent by weight of the cement.

There are no details as to the apparatus used except that readings of 0.0001 in. were obtained. The detailed notes are given showing the deformations read at increments of 50 lb. per sq. in. up to 1000 lb. per sq. in. and then in increments of 100 lb. per sq. in.

Some of the columns showed a permanent set of 0.0003 in. in the 50-in. gage length at a unit stress of 150 lb.; the richer mixes, however, showed no permanent set up to unit stresses of 500 lb. per sq. in.

The modulus of elasticity is given for stress ranges of 100 to 600, 600 to 1000, 1000 to 1500, 1500 to 2000 and 2000 to 2500 lb. per sq. in. These values show a decrease as the stress increases.

The following are some of the values given for plain columns between the stresses of 600 to 1000 lbs. per sq. in.

Mix	Water-Cement Ratio, per cent	Compressive Strength, lb. per sq. in.	Age, months	Modulus of Elasticity, lb. per sq. in.
1:1	0.324	3555	8½	2 564 000
1:2	0.36	2824	8	2 410 000
1:3	0.45	1938	8	2 041 000
1:4	0.54	1427	8	1 389 000
1:5	....	1117	8	948 000
1:6	0.90	834	7½	830 000

1908

(18) Humphrey, R. L., "The Strength of Concrete Beams," *Bulletin 344*, U. S. Geological Survey.

This report contains data obtained from the testing of a series of 8 by 16-in. compression cylinders. The values given are initial tangent moduli of elasticity.

Materials.—Cement, blend of several brands; sand, Meramec River sand from Drake, Mo., specific gravity 2.597, 37.9 per cent voids, 100.6 lb. per cu. ft.; Coarse aggregate: (1) Cinders, specific gravity 1.530, 50.7 per cent voids, wt. cu. ft. 47.0; (2) Granite, specific gravity 2.585, 40.9 per cent voids, wt. cu. ft. 95.3; (3) Gravel, specific gravity 2.450, 33.0 per cent voids, wt. cu. ft. 102.4; (4) Limestone, specific gravity 2.489, 37.1 per cent voids, wt. cu. ft. 97.7 (maximum size of coarse aggregate 1¼ in.).

Consistencies.—"Wet, medium and damp." The percentage of water varied between 18.5 to 22.4 per cent for cinder concrete, 6.9 and 9.2 per cent for granite concrete, 7.6 and 9.9 per cent for gravel concrete, 8.4 and 11.0 per cent for limestone concrete.

Proportions.—1:2:4 for all except cinder concrete. For this the proportions ranged from 1:2:4.79 to 1:2.06:5.4.

Age of tests.—28 days, 13 weeks and 26 weeks.

Storage.—In laboratory 12 to 16 days, after which they were removed to a damp room. The temperatures were about 70° F. in both and the specimens were sprinkled three times a day.

Apparatus.—Not described.

Average Values (Table 10 of report):

Coarse Aggregate	Consistency	Modulus of Elasticity, lb. per sq. in.		
		At 28 days	At 13 weeks	At 26 weeks
Cinders	Wet	1 236 000	2 657 000	1 610 000
	Medium	1 352 000	2 275 000	1 618 000
	Damp	1 288 000	1 635 000	1 382 000
Granite	Wet	3 570 000	4 283 000	4 057 000
	Medium	4 083 000	4 747 000	3 913 000
	Damp	4 890 000	4 697 000	4 430 000
Gravel	Wet	3 787 000	4 890 000	4 050 000
	Medium	3 875 000	5 200 000	4 660 000
	Damp	4 070 000	5 160 000	4 873 000
Limestone	Wet	3 588 000	3 983 000	3 423 000
	Medium	3 432 000	3 963 000	3 943 000
	Damp	4 257 000	4 660 000	4 310 000

1909

(19) Withey, M. O., "Tests of Plain and Reinforced Concrete Columns," *Bulletin No. 300*, University of Wisconsin, Vol. 5, No. 2.

In connection with the general program the modulus of elasticity and compressive strength of a number of 6 by 8-in. cylinders was determined.

Materials.—Cement, Atlas portland; sand, clean but rather fine; stone, soft crushed limestone (0.14 to 1 in.); water, from 9.5 to 10 per cent of the weight of the sand, stone and cement.

No mention is made of the apparatus used for measuring deformations in the 6 by 8-in. cylinders. In testing the columns deformations were measured using the copper wire, dial compressometers described by Withey in his earlier reports of these tests.

It is indicated that the average stress-strain curve obtained in these tests is parabolic in form. Tests on 35 cylinders are tabulated. The age of the specimens ranged from 54 to 63 days. The modulus of elasticity values varied between 2,600,000 and 3,400,000 lb. per sq. in. at one third of the ultimate load (which averaged 2275 lb. per sq. in.).

The moduli of elasticity of the columns are given in another table. The values range from 1,700,000 to 4,200,000 lb. per sq. in., being influenced by the reinforcement present. A number of stress-strain curves are given for different size columns.

The plain concrete columns (1:2:4) of series A had an average modulus of elasticity of 3,850,000 lb. per sq. in. at one-third of the ultimate load.

The tests of the cores of the latticed angle columns of series B, reinforced with 4.5 per cent steel, gave an average modulus of elasticity of 4,100,000 lb. per sq. in.

The columns of series C containing 1.33 per cent spiral reinforcement showed an average modulus of elasticity of 2,200,000 lb. per sq. in. Other specimens which, in addition to this spiral reinforcement, contained 2.35 per cent longitudinal steel showed an average modulus value of 3,100,000 lb. per sq. in.

1910

(20) Goldbeck, A. T., "An Investigation of the Distribution of Stress in Reinforced Concrete Beams, Including a Comparative Study of Plain Concrete in Tension and Compression," *Proceedings*, Am. Soc. Testing Mats.. Vol. X, p. 376 (1910).

Materials.—Alpha portland cement, bank sand, 1½-in. crusher-run dolomite.

Mixes.—1:2:4 and 1:3:6 (by volume).

Consistency.—The concrete was mixed to a consistency such that water was readily brought to the top in molding.

Storage.—In the 1909 series, all specimens were stored in air for 7 days and then placed in water. In the 1910 series all specimens were stored in air.

Specimens.—Compression, 8 by 16-in. cylinders; tension, 8-in. cylinders with ends enlarged to 10 in.

Apparatus.—200,000-lb. testing machine. Compressometer, 12-in. gage length, electrical indicating, reading to 0.0001 in.

Difficulty was experienced in reading extension of the tension specimens because of the small deformations occurring before failure.

Comparison of Concrete in Tension and Compression:

Mix, Storage, etc.	Compressive Strength, lb. per sq. in.	Modulus of Elasticity in Compression, lb. per sq. in.	Tensile Strength, lb. per sq. in.	Modulus of Elasticity in Tension, lb per sq. in.
1:2:4 mix stored 28 days in air	1395	2 420 000	88.5	1 845 000
1:3:6 mix stored 28 days in air	910	2 510 000	75.6	1 395 000
1:2:4 mix stored 7 days in air and 79 days in water	1810	4 800 000	140	4 250 000
1:2:4 mix stored 7 days in air and 70 days in water	1720	4 800 000	145	2 250 000

(21) Withey, M. O., "Tests on Reinforced Concrete Columns," *Bulletin No. 466*, University of Wisconsin, 1910.

As a part of the main program of these tests there were included tests of a considerable number of 6-in. cylinders on which modulus of elasticity determinations were made.

No mention is made of the apparatus used in the modulus of elasticity tests on these cylinders.

Two different sands and four gradings of crushed stone were used as the aggregates. The amount of water varied from 8.7 to 12 per cent. The concrete was mixed in the following proportions: 1:2:3½, 1:2:4, 1:3:6, 1:1.75:3.25, 1:1:2 and 1:1.5:3.0. Mortar specimens of 1:1.29 and 1:1.33 were also made. All measurements refer to dry loose volume.

One curve obtained indicates that the kind of sand used affects the value of the modulus of elasticity.

Another curve using modulus of elasticity as an ordinate and the cement-aggregate (by weight) ratio shows a sharp rise in the modulus of elasticity between the values 0.1 and 0.2, a gradual rise between 0.2 and 0.3 and a horizontal line between 0.3 and 0.5.

A large number of values of the modulus of elasticity are tabulated. These are taken at one-third of the ultimate strength of the concrete. The age, mix, per cent water and strength are noted in the tables. In general the values of the modulus of elasticity range from 1,950,000 to 4,600,000 lb. per sq. in. There is also a table which gives the modulus of elasticity of the columns taken at one-fourth of the ultimate strength of the concrete.

It is shown that there is a very marked change in the modulus of elasticity of the columns with different percentages of longitudinal steel. The value ranged from 2,200,000 for plain concrete (0 per cent steel) to 5,800,000 lb. per sq. in. for 10.12 per cent steel.

1911

(22) Ingberg, S. H., "The Determination of Stresses in a Reinforced Concrete Member Subject to Axial Load and Flexure," *Proceedings*, Am. Soc. Testing Mats., Vol. XI, p. 595 (1911).

There are no details given regarding materials or apparatus used in making the modulus of elasticity tests.

There were ten 8 by 16-in. cylinders tested. The gage length was 10 in.

The average initial modulus of elasticity value was found to be 2,270,000 lb. per sq. in. for concrete having an ultimate strength of 1740 lb. per sq. in.

There is also given a curve showing unit deformation as an ordinate and modulus of elasticity as an abscissa. It shows the initial tangent modulus to be 2,270,000 lb. per sq. in. At a unit deformation of 0.0005 it was 1,820,000. At a unit deformation of 0.0010 it was 1,440,000, and at a unit deformation of 0.0020 it was 960,000 lb. per sq. in. This curve is an average of the data from the entire ten specimens.

(23) Humphrey, R. L., and Losse, L. J., "The Strength of Reinforced Concrete Beams," *Technologic Paper No. 2*, U. S. Bureau of Standards.

In connection with these comprehensive tests, modulus of elasticity determinations were made on a number of specimens. Over three hundred 8 by 16-in. cylinders were tested in this way.

Materials.—All materials were from the vicinity of St. Louis, Mo.; cement, a typical portland; sand, from Meramec River, specific gravity 2.597, voids, 37.9 per cent, weight per cubic foot 100.6 lb.; coarse aggregate: (*a*) cinders, specific gravity 1.750; (*b*) granite, specific gravity 2.585, voids 40.9 per cent, weight per cubic foot 95.3 lb.; (*c*) gravel, specific gravity 2.450, voids 33.0 per cent, weight per cubic foot 102.4 lb.; (*d*) limestone, specific gravity 2.489, voids 37.1 per cent, weight per cubic foot 97.7 lb.

Curing.—Not described.

Apparatus.—Not described other than to say that deformations were measured on both sides of the specimens over a 12-in. gage length.

A graph is shown which indicates the effect of age on the modulus of elasticity of concrete. From this it appears that the gravel concrete had 4,600,000 lb. per sq. in. at the age of 4 weeks, 5,200,000 after 26 weeks, and 5,400,000 after 52 weeks. Limestone specimens showed lower values than the gravel but the growth with age was very similar. The same was true for cinder concrete.

Another figure shows that the elastic limit of the concrete increased with age. For the granite and limestone concretes the elastic limit was about 700 to 900 lb. per sq. in. at four weeks and 1600 to 1800 lb. per sq. in. at one year.

The initial modulus of elasticity at the age of four weeks exceeds 2,500,000 lb. per sq. in., the usually specified value, by about 85 per cent for the gravel, 70 per cent for the granite and 45 per cent for limestone concretes but the cinder concrete shows a modulus of elasticity 35 per cent below this value.

The compressive stress - gross deformation diagram for concrete may be represented by a straight line up to a unit stress which is 1.5 the yield point with an average error of about 4.2 per cent.

The following table shows some average values taken from Tables 33, 34 and 35 of the report:

Coarse Aggregate	Mix	Age, weeks	Water, per cent	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.	Yield Point, lb. per sq. in.
Granite	1:2:4	4	8.2	3054	4 290 000	950
		13	8.2	3979+[a]	4 430 000	1350
		26	8.2	3979+[a]	4 480 000	1700
		52	8.2	5086	4 770 000	1962
Limestone	1:2:4	4	10.0	2492	3 590 000	800
		13	10.03	3600	3 810 000	1450
		26	10.0	3778	4 310 000	1400
		52	10.7	4378	4 550 000	1652
Gravel	1:2:4	4	9.3	3175	4 600 000	1050
		13	9.44	3821+[a]	4 620 000	2100
		26	9.46	3821+[a]	5 240 000	1550
		52	9.47	5242	5 395 000	2129
Cinders	1:2:4	4	18.93	1647	1 610 000	450
		13	18.95	2217	1 820 000	800
		26	18.97	2525	2 120 000	900

Each of the above values represents the average of 21 tests.

[a] Exceeded the capacity of the testing machine.

(24) Wig, Rudolph, "The Effect of High Pressure Steam on the Crushing Strength of Portland Cement Mortar and Concrete," *Technologic Paper No. 5*, U. S. Bureau of Standards.

Some modulus of elasticity tests were a part of this investigation.

The test specimens were 8 by 16-in. cylinders.

The mix used was 1:4. Two consistencies were included: damp (5.5 per cent water) and quaking (9.0 per cent water).

Steam pressures were varied between 2 and 80 lb. per sq. in. The time under steam pressure was varied from 3 to 48 hours. The age of the specimens at the time of test was between 2 and 14 days.

No details are given of the instruments used to measure deformations.

Conclusions:

Steam pressure up to 80 lb. per sq. in. gage pressure has an accelerating effect on the hardening of portland cement mortar and concrete. A compressive strength considerably (in some cases over 100 per cent) in excess of that obtained normally after aging for six months, may be obtained in two days by using steam under pressure for curing the mortar.

The initial modulus of elasticity and the yield point increase directly with the duration of the steam treatment. The initial modulus of elasticity and the yield point increase directly with the steam pressure. The initial modulus of elasticity does not increase in direct proportion to the increase in the compressive strength of the steam-cured mortar.

A few typical data appear in the following table (1:4 mortar, 9 per cent water):

	Gage Pressure, lb.	Duration of Steaming, hours	Temperature, deg. Fahr.	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.
Tested after 2 days	Not steamed		...	676	1 480 000
	2	24	218	1743	1 900 000
	20	24	258	2113	2 000 000
	80	24	323	3959	2 840 000
Tested after 14 days	Not steamed		...	1536	....
	2	24	218	1739	2 160 000
	10	24	239	1690	2 670 000
	80	24	323	4433	....

1913

(25) Strehan, G., and Perrine, H., "An Investigation of the Strength of Cinder Concrete," *Engineering News*, Vol. 70, No. 15, October 9, 1913, p. 722.

As a part of this investigation 120 cylinders 8 by 16 in. in size were tested for crushing strength and modulus of elasticity.

No details are given as to the aggregates used except to say that the cinders were being used in building construction in New York City.

Ages of test, 1, 2 and 6 months.

Electric contact extensometers were used.

Summary of data:

		Mix			
		1:2:5	1:1:5	1:2:5	1:2:5
Age 1 month	Compressive Strength, lb. per sq. in.	407	507	818	980
	Modulus of Elasticity, lb. per sq. in.	924 600	857 400	1 230 000	1 492 000
Age 2 months	Compressive Strength, lb. per sq. in.	701	662	1254	1035
	Modulus of Elasticity, lb. per sq. in.	1 134 000	1 030 000	1 740 000	1 428 000
Age 6 months	Compressive Strength, lb. per sq. in.	933	754	1744	1478
	Modulus of Elasticity, lb. per sq. in.	971 000	1 050 000	1 348 000	1 276 000

1915

(26) Swain, F. W., and Holmes, A. F., "An Investigation of the Strength and Elastic Properties of Concrete-Filled Pipe Columns," *Proceedings*, Am. Soc. Testing Mats., Vol. XV, Part II, p. 230 (1915).

The columns ranged in size from a 4-in. light-weight boiler tube to a 6$\frac{5}{8}$-in. standard weight steam pipe. Their lengths were 8, 10 and 12 ft.

The pipes were filled with a 1:2:3 concrete, using a $\frac{1}{2}$-in. maximum size crushed stone for the coarse aggregate.

No details are given of the apparatus except to say that a 32-in. gage length was used and that deformations were read to 0.0001.

The modulus of elasticity of the concrete, with the permanent set deducted, was 3,125,000 lb. per sq. in. and with permanent set not deducted was 2,605,000 lb. per sq. in.

(27) McMillan, F. R., "Shrinkage and Time Effects in Reinforced Concrete," *Bulletin No. 3*, University of Minnesota, 1915.

These tests were concerned with reinforced-concrete beams but there were a few determinations of the modulus of elasticity of concrete under conditions of short duration loadings.

The concrete was composed of Minneapolis limestone, ordinary bank sand and a standard grade of Portland cement. It was hand mixed in the proportions 1:2:4. The specimens were cured in room temperatures of 60° to 80° F. Four 8 by 16-in. cylinders were tested.

No details are given as to the apparatus used to measure deformations.

The test data are given in the following table:

Age, days	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.
27	2540	3 770 000
27	2430	3 160 000
353	3580	3 780 000
353	2785	3 370 000

1916

(28) Taylor, F. W., and Thompson, S. E., "Concrete Plain and Reinforced," pub. 1916. John Wiley and Son, Inc., New York City.

A few pages are devoted to a discussion of tests to determine the modulus of elasticity of concrete.

"Plotting the results of a large number of tests made at the Watertown Arsenal, at the Government Laboratory at St. Louis and at many of the colleges, indicates an approximate ratio of 1300 between the modulus of elasticity and the ultimate strength."

The authors made some tests which show the effect of consistency on the modulus of elasticity of concrete. The value for a "dry" mix is given as 4,050,000, for a "medium" mix as 4,500,000, and for a "very wet" mix as 2,100,000 lb. per sq. in. No details regarding apparatus or aggregates are given.

(29) Wig, R. J., Williams, G. M., and Gates, E. R., "Strength and Other Properties of Concrete as Affected by Materials and Methods of Preparation," *Technologic Paper No. 58*, U. S. Bureau of Standards.

This paper reports the results of about 20,000 tests.

Compressive and tensile tests were made upon mortars at different ages. The aggregates included about 240 different sands, and stone screenings. Compressive tests were made on concretes composed of 7 sands and 60 different coarse aggregates, including limestones, gravels, granites, cinders and trap rock.

The cement used was a typical Portland cement. Most of the aggregates came from the Middle West. The percentage of water used ranged from 4.5 to 25. Several consistencies designated as dry, moist, plastic, quaking, mushy and fluid were used. Some of the specimens were stored in a damp room at 70° F.; others were exposed to the weather.

Both hand and machine mixing were used.

The test specimens on which the modulus of elasticity determinations were made were 8 by 16-in. cylinders. No details are given as to the apparatus employed for the modulus of elasticity tests.

There are many tables and charts of the data obtained. Table 8 of the report lists the yield point, modulus of elasticity and compressive strength of concretes made with 37 different aggregates. These specimens were of a 1:2:4 mix and were tested at the ages of 4, 13, 26 and 52 weeks. Other tables show similar data for other mixes.

The following values were taken from Figs. 40 and 41 of the report:

Aggregate	Elastic Limit, lb. per sq. in.			Modulus of Elasticity, lb. per sq. in.		
	Age, 1 month	Age, 3 months	Age, 6 months	Age, 1 month	Age, 3 months	Age, 6 months
Limestone	700	1400	1300	2 600 000	3 800 000	4 300 000
Granite	600	700	1500	4 300 000	4 000 000	4 000 000
Gravel	1900	2200	2600	5 100 000	5 800 000	5 400 000
Cinders	400	700	900	1 600 000	1 800 000	2 100 000

(30) McKibben, F. P., and Merrill, A. S., "Tests on Concrete Columns Plain and Reinforced," *Proceedings*, Am. Concrete Inst., Vol. XII, p. 200 (1916).

In these tests thirty-three columns 14 in. in diameter and from 5 to 20 ft. in length were included. Nine of these were plain and 24 were reinforced concrete.

The proportions 1:2:4 were used throughout.

Materials.—Cement, Lehigh Portland; sand, Delaware River; stone, maximum size 1½ in., a very compact granite gneiss; water, 8 per cent of combined weight of other materials.

The columns were cured in the laboratory and the test cylinders in damp sand.

Longitudinal deformations were measured with Wissler dials attached by steel yokes, the shortening of the column being transmitted to the dials by wires fixed to other yokes. The gage lengths used were as follows: 5-ft.column, 40 in.; 10-ft. columns, 80 or 100 in.; and 20-ft. columns, 200 in.

Lateral deformations were measured by two independent yokes. These yokes were held against the column by springs and by the use of extension arms with Ames dials attached to their ends and it was possible to read four times the actual lateral deformation. These values were measured in two directions at right angles.

The average strength of the concrete was 2100 lb. per sq. in. The initial modulus of elasticity of this concrete is shown to be from 2,100,000 to 3,500,000 lb. per sq. in. while at the maximum unit compression it appears to be from 1,020,000 to 1,654,000 lb. per sq. in.

The modulus of elasticity of the reinforced columns is shown to vary with the amount of steel in the spiral reinforcement used. For example, in the 10-ft. columns:

	Reinforcement, per cent	Modulus of Elasticity, lb. per sq. in.
At 500 lb. per sq. in. stress	0	2 330 000
	3.82	3 080 000
At 2000 lb. per sq. in. stress	0.46	1 920 000
	0.96	2 070 000
	1.95	1 710 000
	3.82	1 970 000

1917

(31) Smith, E. B., "The Flow of Concrete Under Sustained Loads," *Proceedings*, Am. Concrete Inst., Vol. XIII, p. 99 (1917).

Concrete cylinders 3 in. in diameter and 24 in. long were loaded to 840 lb. per sq. in. by a dead load, lever system. The concrete was of 1:2:4 proportions, gravel and limestone being used as the coarse aggregate. The specimens were cured in the open air and sprinkled once a day for the first week. They were tested after 28 days.

Deformations were measured periodically with a 20-in. Berry strain gage.

It is shown that the deformation increased with the duration of the load. For example, when the load of 840 lb. per sq. in. was first applied the unit deformation amounted to 0.0004. After six days it had increased to 0.0011 and to 0.0015 at 28 days. The effect of this is to vary the stress-strain relation as a function of time.

(32) Lord, A. R., "Extensometer Measurements in a Reinforced Concrete Building Over a Period of One Year," *Proceedings*, Am. Concrete Inst., Vol. XIII (1917).

This test was made on the Schwinn Building, Chicago, Ill.

No description is given in this paper of the materials in the concrete or of the apparatus used in testing.

A number of 6-in. cubes and 8 by 8 by 16-in. prisms tested at different ages show the following:

Age	Compressive Strength, lb. per sq. in.	Modulus of Elasticity, lb. per sq. in.
67 days	2150	3 700 000
6 months	2570	3 500 000
10 months	2733	4 350 000
14 months	2500	3 400 000

Data are also given showing the increase of deformation for a constant load with time.

1918

(33) Lagaard, M. B., "Saturation of Concrete Reduces Strength and Elasticity," *Engineering News-Record*, Vol. 81, No. 20, Nov. 14, 1918, p. 908.

These tests were confined mostly to compression tests on 8 by 16-in. cylinders. The deformations were measured with a four dial compressometer estimating readings to 0.0001 (on a 10-in. gage length).

The proportions were 1:2:4, both gravel and crushed trap rock being used for coarse aggregate.

Different methods of curing were used. Some specimens were tested wet; others were dry.

"It will be noticed that in all cases the specimens which had been wet the longest show the highest values for the initial modulus of elasticity."

Time, weeks		Secant Modulus of Elasticity at 700 lb. per sq. in. Stress, lb. per sq. in.	Compressive Strength, lb. per sq. in.
Under Burlap	In Air		
1	7	2 530 000	1989
3	5	2 790 000	2434
7	1	3 000 000	2250
8	0	3 170 000	2069

(34) Talbot, A. N., and Gonnerman, H. F., "Tests on an Eight-Year-Old Flat Slab Floor of the Western Newspaper Union Building," *Proceedings*, Am. Concrete Inst., Vol. XIV, p. 192 (1918).

"The concrete in the slab was of a 1:2:4 mix. Pieces of the concrete were cut out from the floor and sawed into test prisms approximately 5 in. square and 16 in.

long. The compressive strength of these test prisms ranged from 3190 lb. per sq. in. in panel B to 5460 lb. per sq. in. in panel A, and the initial modulus of elasticity from 3,500,000 to 5,100,000 lb. per sq. in. The coarse aggregate was gravel."

There are no further details regarding modulus of elasticity.

1919

(35) Carver, T. H., and Quense, J. H., "Tests of Concrete in Tension," *Engineering News-Record*, Vol. 83, No. 21, December, 1919, p. 1005.

Standard portland cement was used and the materials were mixed in the proportions 1:1.42:2.36 for three minutes.

The specimens were 5 in. square and 42 in. in length. They were cured under wet burlap for about 60 days. Ten specimens in all were tested at ages ranging from 57 to 609 days.

An electric contact extensometer of 18-in. gage length and reading to 0.0001 in. was used to measure deformations.

Some of the data were as follows:

Age, days	Tensile Strength, lb. per sq. in.	Average Modulus of Elasticity in Tension, lb. per sq. in.	Age, days	Tensile Strength, lb. per sq. in.	Average Modulus of Elasticity in Tension, lb. per sq. in.
58	268	5 030 000	234	378	5 870 000
57	333	5 830 000	585	445	4 904 000
60	278	5 996 000	609	492	5 785 000

(36) Johnson, J. B., "Materials of Construction," 6th Ed., John Wiley and Sons.

A summary of the values of the modulus of elasticity obtained by a number of investigators is given in this book. The values are tabulated against the following variables: mix, age, method of curing, consistency and range of stress. Since the data from which this table is made is given elsewhere in this digest they are not included in this abstract.

(37) Walker, Stanton, "Modulus of Elasticity of Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. XIX, Part II, p. 510 (1919).

This report is a very comprehensive study of the subject.

Defines modulus of elasticity as "The ratio of an increment of stress to a corresponding increment of deformation."

Presents data based on 9 series of investigations embracing about 10,000 tests of 6 by 12-in. cylinders. The variables studied include size and grading of aggregate, quantity of cement, quantity of mixing water, age of test, kind of aggregate, condition of curing and time of mixing.

Studies were also made to show the variation in modulus of elasticity as affected by stress at which modulus of elasticity is measured and the gage length.

The aggregates included pebbles (Illinois), crushed limestone, crushed granite, crushed blast furnace slag.

Specimens up to 5 years of age were included in these tests.

All tests were made in a 200,000-lb. universal testing machine.

Most of the tests were made with a special clamp type extensometer for which certain claims of superiority are advanced. In this instrument a bottom frame is attached to the specimen by three pointed screws set radially. A top frame is attached by two opposed set screws, it being allowed to rotate about them as an axis

A spacing bar is arranged to hold the two frames or yokes a fixed distance apart along one side of the specimen, causing the one yoke to rotate and thus record the deformation by displacing the stem of an Ames dial. This design transmits to the micrometer dial a motion equal to twice the total longitudinal deformation of the specimen.

A very complete discussion of the data is presented, following which the following conclusions are drawn:

1. The relation of compressive stress to deformation for concrete may be represented by the equation

$$s = Kd^n$$

where s = unit stress of concrete, d = unit deformation of concrete, K a constant which depends on the strength of the concrete, and n = an exponent approximately constant. The curve represented by this equation has a decreasing slope and gives decreasing values of modulus of elasticity as the stress is increased.

2. The modulus of elasticity of the concrete is a function of the compressive strength. The relation between modulus of elasticity and strength for mixtures leaner than about 1:3 may be represented by an equation of the form

$$E = CS^m$$

where E = modulus of elasticity of the concrete, C = a constant depending on the conditions of tests, S = compressive strength of the concrete, m = an exponent.

For the initial tangent modulus the average of our tests may be expressed by the equation

$$E_i = 33000\ S^{\frac{5}{8}}$$

For the tangent modulus at 25 per cent of the compressive strength the equation becomes

$$E_{t25} = 66000\ S^{\frac{1}{2}}$$

The ratio of modulus of elasticity to strength, as shown by these equations, varies from about 3300 for the initial tangent for 500 lb. per sq. in. concrete, to 1400 for 5000 lb. concrete. The corresponding values for the tangent values at 25 per cent of the compressive strength are about 3000 to 940, respectively.

3. (*a*) Both the modulus of elasticity and strength increase within certain limits as the aggregate becomes coarser, although the modulus of elasticity increases less rapidly than the strength.

(*b*) An increase in the quantity of cement in the batch causes an increase in values of modulus of elasticity and strength. The modulus of elasticity is affected somewhat less by change in the cement than is the strength.

(*c*) The quantity of mixing water exerts a most marked effect on the modulus of elasticity and strength. An addition of 25 per cent of water to a mixture of normal consistency decreases the modulus of elasticity about 15 to 20 per cent and the strength about 35 to 40 per cent.

(*d*) Both the modulus of elasticity and strength increase with the age of the concrete so long as the specimens are kept moist during curing. The strength increases in proportion to the logarithm of the age. The modulus of elasticity follows approximately the same relation.

(*e*) There is no marked difference in the modulus of elasticity and strength of concrete made of high-grade pebbles, crushed granite, limestone or blast-furnace slag.

(*f*) A comparison of specimens stored 14 days in damp sand and 77 days in air with specimens stored 91 days in damp sand shows that both the modulus of elasticity and strength are higher for the damp sand storage.

(*g*) Tests for mixing times ranging from $\frac{1}{4}$ to 10 minutes show both the modulus of elasticity and strength to be greater for the longer mixing times.

4. The secant and tangent moduli of elasticity are less for the higher loads. At a given percentage of the strength these values vary approximately in direct proportion to the initial tangent modulus for concrete of ordinary strengths.

5. Deformations measured over gage lengths ranging from 4 to 10 in. on a 6 by 12-in. cylinder show that the gage length exerts only a slight influence on the modulus of elasticity.

6. The inter-relation of modulus of elasticity to strength and the proportions of the concrete is sufficiently definite to make possible the construction of a monographic chart. While the absolute values given on this diagram cannot be taken to be representative of concrete made under all conditions, it gives values which stand in the proper relation to each other.

7. A study of the stress deformation data for a number of materials, including woods, metals, stone, brick, brick piers, rubber, rope and concrete of many kinds, indicates that the relation expressed by the equation under conclusion 1 is applicable to all materials.

8. A study of the action of two extensometers used for these tests showed that the Ames dial gave much more uniform results than the Johnson wire-wound dial.

9. Values of modulus of elasticity should be the average of 10 or more tests to secure concordant results.

10. The point where the law expressed by the equation under conclusion 1 no longer holds is approximately the same as that called the "yield point" of concrete by certain writers. Values of "yield point" obtained in this way varied from 50 to 90 per cent of the compressive strength.

In discussion of Mr. Walker's paper, the following comments were offered:

Mr. Hollister.—Mr. Hollister claims that the curvature of Mr. Walker's curves near the origin is possibly due to instrumental error and presents some data which indicates such a possibility.

Further, he does not accept Mr. Walker's definition of modulus of elasticity. He claims that an elastic deformation is one which will entirely disappear when the stress causing it is removed. Definition "Thus the modulus of elasticity, in the writer's opinion, is the ratio of an increment of stress to the corresponding increment of *elastic* deformation."

Mr. Williams.—"The belief that the stress strain relation is represented by a curve such as the above [Mr. Walker's] is not justified for stresses below and well above those used in concrete design. Repeated loading tests on the same specimens show that the relation is linear and as well defined and constant for any particular specimen as is the stress-strain relation of steel."

1920

(38) Williams, G. M., "Some Determinations of Stress-Deformation Relations for Concretes Under Repeated and Continuous Loadings," *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part II, p. 233 (1920).

Materials.—Portland cement, Potomac River sand and gravel and blast furnace slag.

Specimens were 8 by 16 in. in size and were for the most part stored in damp sand until the time of test.

Apparatus.—200,000-lb. universal testing machine using spherical bearing blocks. Extensometer, two independent yokes, each having three points of contact.

Three 0.0001-in. Ames dials were used to measure the deformations over a 10-in. gage length.

Most of the work was done on 1:2:4 concrete but some specimens of other mixes were included. In some cases the loads were repeated a number of times, while in others the loads were sustained for some time.

Some of the specimens were tested dry and others after being in water for 10 days. Also some attempt was made to determine the effect of "flowability" on the modulus of elasticity.

Summary:

1. "The true stress-deformation relation for concrete under loads even exceeding designing loads and loads applied in practice and up to 50 or 75 per cent of the ultimate strength may be represented by a straight line."
2. "For a few specimens composed of a lean mix or very wet consistency concretes just removed from damp sand storage, it was found that the increments of deformation for equal increments of load, for the first application of load only, could be represented by an equation of the exponential type, but second and additional applications of load resulted in a straight line relation."
3. "For ordinary working loads, and up to 50 to 70 per cent of the ultimate strength of the concrete, 95 per cent of the value for modulus of elasticity obtained by dividing the unit stress by the unit deformation for that load will represent the true modulus of elasticity with sufficient accuracy."
4. "The modulus of elasticity for normal concretes is the same for any given material in either the wet or dry condition."
5. "The modulus of elasticity of concrete is apparently increased slightly for repeated or long-continued single applications of loads. The modulus of elasticity of concrete in a structure subjected to loads within design limits is probably slightly greater than the value found from tests of cylindrical specimens of the same concrete. The stress-deformation relation under such conditions can be represented by a straight line."
6. "With any given cement and grading of aggregate of the same maximum size and for any given proportion of cement to aggregate, the ratio of modulus of elasticity to compressive strength of concrete is fairly constant regardless of the consistency or 'flowability.' "

In discussion of the paper, Mr. Walker objected to the straight line conclusion and presented some data to corroborate his own paper.

1924

(39) Johnson, A. N., "Direct Measurement of Poisson's Ratio for Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 1024 (1924).

The specimens consisted of 4½ by 9-in. cylinders or drilled cores (from Maryland highways). The mixes were 1:2 mortar (age 2 and 13 months), 1:2:3 concrete (age 12 months), 1:2:4 concrete (age 6 months) and 1:2:4 concrete drilled cores (age 12 months, 7 years and 8 years).

Loads were applied by hand operation of a universal testing machine.

A mirror extensometer of the Marten's type was used to measure the longitudinal strain. The primary object of the investigation was the determination of Poisson's ratio. Dean Johnson's apparatus was designed for this purpose and further description will be omitted.

There are no actual values of modulus of elasticity given, but there are considerable data on stress-strain relations for concrete of various mixes and ages.

1925

(40) Hatt, W. K., "Researches in Concrete," *Bulletin No. 24*, Purdue University.

There is a short article in this bulletin on elasticity in concrete in which Mr. Hatt discusses definitions and gives a short summary of the work of other investigators with some tabulated data.

The original sources are abstracted elsewhere in this digest.

1926

(41) Johnson, A. N., "Concrete in Tension," *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part II, p. 441 (1926).

In this paper Dean Johnson makes a few remarks on the modulus of elasticity of concrete, citing the fact that when the strain is measured with the mirror extensometer (Marten's type) the portion of the curve up to the elastic limit of the concrete is a straight line.

1928

(42) Davis, R. E., "Flow of Concrete Under Sustained Compressive Stresses," *Proceedings*, Am. Concrete Inst., Vol. XXIV, p. 303 (1928).

These tests were conducted in 1925 and 1926. In the 1925 series, 24 specimens were subjected to sustained load. The temperature at 70° F. and the relative humidity at 70 per cent.

In the 1926 series, forty-five 4 by 16-in. cylinders were subjected to constant compressive stresses ranging from 200 to 1200 lb. per sq. in. Fifteen control specimens were used for applying corrections to the cylinders which were stressed.

The concrete was made in the proportions 1 part cement to 3.01 parts fine aggregate, 1.15 parts medium-sized aggregate, and 0.89 part of coarse aggregate (measured by weight), the maximum size of the aggregate being 1½ in. The water cement ratio was 1.03 by volume. The average slump was 3.2 in.

Some of the specimens were cured under water, others in damp sand. Part of the specimens were in air during the period of sustained loads and part were under water during this period. The age at test varied between 2 days and 3 months. The sustained loads stressed the cylinders between 200 and 1200 lb. per sq. in.

A car spring reacted against one end of the cylinder and a clamp was used in maintaining the constant load.

In the 1925 series deformations were measured with a 20-in. Berry strain gage In the 1926 series observations were taken with a 10-in. fulcrum plate strain gage.

Some of the data are given in the following table:

Mix	Storage	Fineness Modulus	Ultimate Compressive Strength, lb. per sq. in.	Secant Modulus of Elasticity at 1000 lb. per sq. in. Stress, lb. per sq. in.
1:4	Air	6.60	4540	4 090 000
1:4	Air	3.52	3600	3 170 000
1:7	Air	6.60	2170	3 570 000
1:7	Air	3.52	2160	2 470 000
1:4	Water	6.60	3850	5 380 000
1:4	Water	3.52	3320	4 670 000
1:7	Water	6.60	1990	3 080 000
1:7	Water	3.52	1890	3 060 000

The specimens in the above table had been under stress for 5 months. When this was released a newly applied instantaneous load was applied and the modulus of elasticity and compressive strength determined.

Other interesting data of the effect of storage conditions and of duration of load on the modulus of elasticity are given in the following table:

Age at Test	Period of Sustained Load	Stress, lb. per sq. in.	Secant Modulus of Elasticity, lb. per sq. in.	
			Air Storage	Water Storage
7 days	0	300	....	1 500 000
	7 days	300	....	1 100 000
	1 month	300	....	970 000
	9 months	300	....	870 000
28 days	0	300	3 800 000	3 800 000
	7 days	300	2 000 000	2 700 000
	1 month	300	1 400 000	2 300 000
	3 months	300	1 000 000	1 900 000
	9 months	300	850 000	1 500 000
3 months	0	300	4 300 000	4 300 000
	1 month	300	1 800 000	2 300 000
	9 months	300	1 100 000	2 000 000
	0	600	3 200 000	3 200 000
	1 month	600	1 600 000	2 100 000
	9 months	600	980 000	1 700 000

The ratio of the secant modulus at a given stress at time of loading to the secant modulus after a period of sustained load, appears not to vary largely, regardless of the magnitude of the sustained stress and regardless of the age at time of loading. These indications are illustrated in the following table:

Age at Loading	Stress, lb. per sq. in.	Ratio of Elastic Limit to Total Secant Modulus of Elasticity			
		Specimen in Air 7 days	Specimen in Air 3 months	Specimen Under Water 7 days	Specimen Under Water 3 months
7 days	300	...	...	0.7	0.6
	600	...	...	0.7	0.6
28 days	300	0.5	0.2	0.7	0.4
	600	0.6	0.3	0.7	0.5
	900	0.6	0.4	0.7	0.6
3 months	300	0.5	0.3	0.6	0.5
	600	0.6	0.3	0.8	0.5
	900	0.7	0.4	0.8	0.6
Average	....	0.6	0.3	0.7	0.5

(43) Johnson, A. N., "Strength Characteristics of Concrete," *Public Roads*, Vol. 9, No. 9, p. 177.

No details are given concerning aggregate, percentage of water and method of curing. The instrument used is the mirror type extensometer previously described by Dean Johnson. Crushing strengths and moduli of elasticity are tabulated. One group of 1:2 mortar cylinders tested at from 7 to 30 days showed an average crushing strength of 2842 and an average modulus of elasticity of 3,165,000 lb. per sq. in. Another group tested at ages of 52 days to 3 years showed an averge crushing strength of 3754 and a modulus of elasticity of 3,438,000 lb. per sq. in.

Another table lists similar values for 1:2:3 concrete cylinders. At ages of 7 to 30 days the average crushing strength of the group was 1649 and the modulus 3,840,000 lb. per sq. in. At ages of 52 days to 2 years these values were 2618 and 3,124,000 lb. per sq. in.

A few tests of 1:2:4 concrete tested at the age of 6 months showed an average crushing strength of 2600 and a modulus of 3,646,000 lb. per sq. in.

Data are given to show that storage in water and testing while wet reduces the magnitude of both the crushing strength and the modulus of elasticity. This was found to be true both for mortar and concrete.

(44) Johnson, A. N., "The Modulus of Elasticity of Cores From Concrete Roads," *Public Roads*, Vol. 9, No. 8, p. 164.

The cores were drilled from Maryland highways during the period between 1921 and 1926. No details are given as to mix, sand or percentage of water. The coarse aggregates were granite, limestone, trap and quartz gravel. The age at the time of test ran all the way from 1 to 10 years.

The instrument used was the mirror extensometer previously mentioned (Marten's type). This instrument permitted the estimation of displacements to 0.00001 in. Some discussion of instruments is presented. The indication is that the mirror type instrument gives a straight line stress-strain relation for concrete (up to the elastic limit, which lies between about 600 and 1000 lb. per sq. in. stress).

Load deformation curves for a number of specimens are given as well as a tabulation of the modulus of elasticity of 112 cores. The average crushing strength was 3960 and the average modulus was 3,562,000 lb. per sq. in. The average elastic limit was between 700 and 800 lb. per sq. in.

It is indicated that there is no definite relation between modulus of elasticity and compressive strength.

Twelve rock cores were tested. Trap rock showed a straight line relation up to 14,000 lb. per sq. in. with a modulus of elasticity of 13,300,000 lb. per sq. in. Granite showed an elastic limit in excess of 2,000,000 lb. per sq. in. and a modulus of 8,660,000 lb. per sq. in. Sandstone showed a curvature up to 9000 lb. per sq. in. After that stress a straight line with a slope of 7,400,000 lb. per sq. in. is indicated. Limestone showed a straight line up to 4500 lb. per sq. in. with a modulus of 4,000,000 lb. per sq. in.

(45) Johnson, J. W., "Relationship Between Strength and Elasticity of Concrete in Tension and in Compression," *Bulletin No. 90*, Iowa State College.

The following series of tests were made to determine the relationship between strength and elasticity as affected by (1) age and consistency, (2) proportions with a constant water-cement ratio, (3) the use of limestone as a coarse aggregate, (4) the application of repeated loadings, (5) type of cement (Atlas Lumnite and a blend of three brands of portland).

Both limestone and gravel aggregates were used, the maximum size being 1½ in. All proportioning was by weight. The proportions used were 1:2.13:4.26, 1:2.17:2.17, 1:1.71:3.47, 1:2.25:1.85, 1:1.93:2.91, 1:2.30:1.54, 1:2.06:2.53, 1:3.0:0.0.

The specimens were 4 by 6 by 36-in. beams, 4½ by 9-in. cylinders and 4 by 4 by 16-in. briquets for direct tension. All were cured in a damp room at 70° F.

A mirror extensometer was used to measure deformations.

The secant moduli of elasticity at 25, 50 and 75 per cent of the ultimate strengths are the values considered in these studies. These values for both tension and compression are tabulated.

Summary of Conclusions:

1. "The moduli of elasticity in tension and in compression for loads up to 50 per cent of the ultimate may be considered equal for design purposes......"

2. For any load above 25 per cent of the ultimate there is a small deformation not recovered upon removal of the load.

3. The stress-strain relationship is a curve for the first application of the load.

4. The stress-strain relationship after the first application of load up to the stress of the first loading is practically a straight line for compression and approaches a straight line for tension.

5. The strength - modulus of elasticity relationship is a curve, the modulus increasing less rapidly than the strength.

6. With other variables constant the modulus of elasticity of portland cement concrete will be different than that for Lumnite cement concrete.

7. The modulus of elasticity of concrete made with limestone aggregate is lower than that of an equal strength concrete made with gravel aggregate.

Figures are given to show the relation between both the compressive and tensile strengths and the modulus of elasticity.

(46) Richart, F. E., Brandtzaeg, A., and Brown, R. L., "A Study of the Failure of Concrete Under Combined Compressive Stresses," *Bulletin No. 185*, University of Illinois.

This investigation was carried out in two parts, (1) a study of concrete specimens loaded in compression in one, two or three directions at right angles to each other by means of fluid pressure, and (2) a study of plain and spirally reinforced concrete compression specimens loaded in one direction in the usual manner.

The object of the investigation was to ascertain how the ability of concrete to resist stress in one direction is influenced by the presence of stresses in the other direction. Although more or less incidental to the investigation this bulletin contains valuable modulus of elasticity data.

Three series of tests are reported in this bulletin: series 2 included 48 4 by 22-in. concrete cylinders subjected to two-dimensional compression, series 3A consisted of tests of 64 4 by 8-in. concrete cylinders in three-dimensional compression, and series 3B tests of 48 4 by 22-in. concrete cylinders in three-dimensional compression.

Longitudinal stress was induced by a testing machine while lateral stresses resulted from liquid pressure on the sides of the cylinders.

Materials.—Universal portland cement, sand composed of calcareous, siliceous and granitic particles (fineness modulus 3.55), gravel of quality similar to the sand and a fineness modulus of 6.67.

Proportions.—8 mixes 1:1, 1:2, 1:3, 1:1:2, 1:2.1:2.5, 1:2:4, 1:3:5 and 1:4:7 (loose volume).

Curing.—Damp closet.

Age.—28 days.

Apparatus.—Extensometer of the micrometer dial type for measuring axial deformations on a 15-in. gage length were attached.

The initial modulus of elasticity values for the specimens tested in simple compression are tabulated for the various mixes. These range from 1,480,000 to 3,070,000 lb. per sq. in. Stress-strain curves for these specimens are given. The 1:1 and 1:2 mortar specimens show a very slight curvature while the lean concretes show pronounced curvature.

Pressure elongation curves are given for the specimens in biaxial compression. Again the rich mixes show but slight curvatures while for the lean mixes it is quite marked.

Load-deformation curves for specimens in simple compression show very little curvature for the rich mixes and pronounced curvature for lean mixes.

The data for the three-dimensional compression show that the initial slope of the load deformation curve is changed under the influence of lateral pressure. For example, with zero lateral pressure, the maximum unit axial load was 2575 lb. per sq. in. and the initial slope was 3,420,000 lb. per sq. in. With 180 lb. per sq. in. lateral pressure the maximum axial load was 3420 lb. per sq. in. and the slope was 1,220,000 lb. per sq. in., while with 4090 lb. per sq. in. lateral pressure the maximum axial resistance was 17,670 lb. per sq. in. and the initial slope of the load deformation curve was 1,150,000 lb. per sq. in.

"A striking difference is seen between the average initial modulus of elasticity in the specimens tested in simple compression and the slopes of the initial tangents for the specimens tested in three dimensional compression, the latter being consistently from one-fifth to one-half of the former.

1929

(47) Richart, F. E., Brandtzaeg, A., and Brown, R. L., "The Failure of Plain and Spirally Reinforced Concrete in Compression," *Bulletin No. 190*, University of Illinois.

This bulletin deals with an investigation of the action of concrete under compressive stresses applied in one or more directions and is a continuation of the work reported in *Bulletin No. 185* of the Engineering Experiment Station. Some data concerning the modulus of elasticity are included.

In these tests longitudinal, radial and circumferential deformations are measured for both plain and spirally reinforced compression specimens.

The materials used were identical with those described in *Bulletin No. 185.* A water-cement ratio of 0.87 was used with a mix of 1:2.1:2.5 (loose volume) resulting in a slump of 6.9 in. and a flow of 215. All specimens were 10 in. in diameter and 40 in. long. Five sizes of mild steel were used for the spiral reinforcement, $\frac{1}{8}$, $\frac{3}{16}$, $\frac{1}{4}$, $\frac{5}{16}$ and $\frac{3}{8}$ in.

Dial type extensometers were used on 4, 8 and 30-in. gage lengths.

The results of the tests are summarized in tabular form and numerous stress-strain curves for each of the types of deformation measured are included.

The effect of the steel reinforcement on the initial modulus of elasticity is shown.

Some discussion of the release and reapplication of load and its effect on the elastic behavior of the specimen is given. "It appears that . . . the slope (of the curve) during reapplication of the load was, on the average, about two-thirds as great as the initial modulus of elasticity."

(48) Davis, R. E., and Troxell, G. E., "Modulus of Elasticity and Poisson's Ratio for Concrete, and the Influence of Age and Other Factors Upon These Values," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 678 (1929).

This paper describes long time tests of concrete cylinders to determine the axial and lateral deformations produced by axial loads.

Scope.—The tests were divided into four series as follows:

Series 1, begun in 1925 and extending over a period of 3 years, to determine the influence of age and richness of mix upon the modulus of elasticity and Poisson's ratio;

Series 2, begun in 1926 and still in progress, to determine the effect of age and of repeated applications of stress upon the modulus of elasticity and Poisson's ratio;

Series 3, extending through 1928, to determine the influence of moisture content upon the modulus of elasticity;

Series 4, begun in 1926 and still in progress, to determine the effect of constant sustained stress upon the stress-strain ratio (here called the sustained modulus of elasticity).

The specimens for the first three series (numbering about 300) were 6 by 12-in. cylinders; those for the fourth series (numbering more than 50) were 4 by 14-in. cylinders.

Materials.—Series 1, Santa Cruz cement, aggregate mix (Monterey sand, metamorphic screenings and crushed metamorphic sandstone in definite proportions).

Series 2, Colton Portland cement and crushed granite.

Series 3, Portland cement, sand and a coast range gravel.

Series 4, Portland cement and crushed granite.

Mixes.—Series 1, 1: 3½, 1: 4½, and 1: 6 (by volume). Series 2, 1: 5. Series 3, 1: 1⅔: 2, 1: 2½: 3, 1: 3¾. Series 4, 1: 5.

Apparatus.—For the tests of Series 1 and 2, axial and lateral deformations were determined by a mirror type apparatus described by A. N. Johnson.[1] For Series 3 the axial deformations were measured with a compressometer of the ring type equipped with a "last-word" dial and using an 8-in. gage length. For Series 4, axial deformations were measured with a 10-in. strain gage of the plate fulcrum type.

Sustained loads were applied by means of a steel frame enclosing a steel coiled spring and the specimen. Compression of the coiled spring exerted a load on the specimen.

Summary of Results.—The results of compression tests on concrete having to do with the effect upon the modulus of elasticity of age, richness of mix, repeated loads, sustained loads and moisture conditions, are given below:

1. The modulus of elasticity, under the conditions of these tests, increases with age for a considerable period of time. At the end of 3 years in damp sand storage there is no evidence that the maximum value has been reached, though the rate of increase is so small as perhaps to be negligible.

2. The increase in the modulus of elasticity is rapid at the early ages and its rate decreases quite uniformly with time. At the later ages the moduli for rich mixes continue substantially to increase after the moduli for the lean mixes have become practically constant.

3. In general, the richer the mix, other things remaining constant, the higher the modulus of elasticity. But under certain conditions at least an increase in the cement ratio produces a decrease in the modulus as is indicated by Series 1 for which the moduli for the 1:3½ mix, except at the later ages, are less than the corresponding values for the 1:4½ mix.

4. Other things remaining equal, the modulus of elasticity of a given concrete when the pore spaces are filled with water, is materially greater than for the same concrete when air dry. That is, while the effect of free moisture within the mass is to decrease the compressive strength, the modulus of elasticity is thereby increased.

5. The sustained modulus after a prolonged period of sustained stress is but a fraction of the instantaneous modulus and this fraction is greater for high stresses than for low ones.

6. The sustained modulus of elasticity is substantially higher for a wet concrete than for the same concrete when air dry.

7. The effect of a load applied at an earlier age is to increase the modulus of elasticity when the same load is applied at a later age.

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[1] A. N. Johnson, "Direct Measurement of Poisson's Ratio for Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 1024 (1924).

APPENDIX XII

DIGEST OF TEST DATA ON POISSON'S RATIO FOR CONCRETE

By F. E. Richart[1] and N. H. Roy[2]

Poisson's ratio is the name generally applied to the ratio between lateral and longitudinal unit strains in a simple tension or compression member. Considered as an elastic constant for a material like concrete, the name should strictly be applied only to values of the ratio at initial loads.

Due to the fact that Poisson's ratio is not considered in most problems of concrete design, no very comprehensive studies of this property of concrete have been made. A number of observations have been made in connection with concrete column tests, although the initital values of the ratio have little bearing on the load-carrying capacity of such columns. Need for a knowledge of the ratio is generally found in the investigation of concrete slabs, arch dams or other statically indeterminate structures.

In this digest reference is made to the work of Talbot, Withey, Davis and Troxell, Johnson, Jasper, Richart, Brandtzaeg and Brown, Wrentmore, Brodie and Carey, Sturm and McMillan. A summary of each series of tests is followed by general discussion of all of the tests.

Talbot, A. N., "Tests of Concrete and Reinforced Concrete Columns," *Bulletin No. 20*, Engineering Experiment Station, University of Illinois, 1907.

The test pieces were plain concrete columns, 12 in. in diameter and 10 ft. in length. The concrete was of proportions 1:2:4 by loose volume, with limestone as the coarse aggregate, and the columns were generally tested at the age of 60 days. Two methods of measuring lateral deformation were used. In one, a circumferential wire girdle, resting on eight standards having four points of contact with the concrete, encircled the column. The ends of the wire were attached to dial extensometers, which indicated the circumferential expansion of the column. By the second method the change in diameter of the column was measured by an attached instrument, the movement being amplified by a lever and measured by an extensometer dial. The measurements of Poisson's ratio were stated to be preliminary in character. The values found varied from 0.10 to 0.18 at early loads, with values reaching 0.25 to 0.30 as the ultimate load was approached.

Withey, M. O., "Tests of Reinforced Concrete Columns," *Bulletin No. 466*, University of Wisconsin, 1911.

The tests covered plain and reinforced concrete columns, 10 to 12 in. in diameter and 8½ to 10 ft. in length. The age at test was generally 50 to 60 days. For measuring longitudinal deformations copper-wire dial compressometers were used. Lateral deformations were measured at mid-height of column by means of a collar device. A steel collar carried a 5:1 multiplying lever and a wire-wound dial by means of which the change in diameter of the column was amplified and measured. Tests indicated that this instrument was sensitive to a lateral unit deformation of 0.000002, which insured quite satisfactory precision. Two series of columns were tested, and Poisson's ratio was determined at one-fourth the ultimate load.

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Series 1.—The mixtures used were 1:2:4 and 1:2:3½. Three plain columns at the age of 53 days gave values of Poisson's ratio of 0.095 to 0.137. Columns with longitudinal and spiral reinforcement gave values of 0.08 to 0.155 at one-fourth ultimate load. For these columns, the reinforcement might be expected to affect the ratio and furthermore the deformations at one-fourth ultimate load were larger than in plain columns.

Series 2.—All columns contained 1 per cent of spiral steel. The mixture varied from 1:3:6 concrete to 1:1⅓ mortar. The longitudinal steel varied from 0 to 6 per cent. The ratios of lateral to longitudinal deformation at one-fourth ultimate load showed no definite effect of the amount of reinforcement present; the values varying from 0.08 to 0.20.

The values reported in this bulletin may be summarized as follows: for plain concrete, 1:2:4, the ratio is 0.10 to 0.14; for columns with spiral reinforcement, the ratio is 0.11 to 0.19; for columns with spiral and vertical reinforcement, the ratio is 0.08 to 0.20.

"Tests of Reinforced Concrete Columns," Report of Committee on Reinforced Concrete and Building Laws, *Journal*, Am. Concrete Inst., July, 1915.

Twenty-four columns, of which two were of plain concrete, were tested. They were made of 1:1½:3 gravel concrete, and were 21 in. in diameter. The column shaft exclusive of capitals at the ends was 9 ft. 4 in. in length. Measurements were taken on both longitudinal and lateral gage lines by means of an 8-in. Berry strain gage. A study of the results of the test of columns 7 and 7A, plain concrete, shows that the ratio of lateral to longitudinal strains varied considerably at different points of the column. For column 7, the average for 20 points on the column was 0.21 at one-fourth the ultimate load and about the same up to three-fourths the ultimate load. Beyond this the ratio increased rapidly. For column 7A, the ratio was 0.23 to 0.28 over the same range of loads. Values of the ratio for the reinforced concrete columns were quite variable, averaging for a number of cases from 0.13 to 0.19 at about one-fourth the ultimate load.

Wrentmore, C. G., Brodie, H., and Carey, C. O., "Report on a Series of Tests on Concrete Columns Reinforced with a Spiral of Steel," *Transactions*, Am. Soc. Civil Engrs., Vol. 78, p. 97, 1915.

The test specimens were columns 4 in. in diameter and 27 in. in length. The concrete was 1:2:4, made with bank sand and ¾-in. broken limestone. A part of the columns were of plain concrete, the remainder had spiral reinforcement. Mirror extensometers were used for both lateral and axial strain measurements. In the lateral extensometer, the mirror multiplication was combined with a mechanical lever system. The smallest strains readable were given as 0.00000025 laterally and 0.0000016 axially.

The values of Poisson's ratio found were somewhat irregular at stresses below 500 lb. per sq. in. The minimum value of the ratio was found at stresses from 100 to 500 lb. per sq. in., and with higher stresses the ratio increased.

Data on the effect of age were not entirely consistent, but generally showed some increase in Poisson's ratio with age. Values of the ratio for stresses of 400 to 700 lb. per sq. in. on plain concrete were 0.19 at ages of 37 days, 0.13 at ages of 67 and 300 days and 0.15 at 426 days. The columns with spiral reinforcement all showed an increase in the ratio as the age increased from about one month to one year, the values at 35 to 49 days (for stresses of 400 to 700 lb. per sq. in.) averaging 0.12, and at 343 to 411 days, 0.14.

Jasper, T. McL., "Determination of Poisson's Ratio and a Suggestion for Its Use in Stress Analysis," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 1012 (1924).

This paper describes direct and indirect measurements of Poisson's ratio for metals and describes methods that might be adapted to concrete specimens. The direct method is the usual one of measuring longitudinal and lateral deformations of the test specimen. The indirect method follows from the relation that Poisson's ratio, μ, is a function of the modulus of elasticity E, and the modulus of shear, or rigidity, F:

$$\mu = \frac{E}{2F} - 1$$

Thus by measuring the deformations of the same test specimen under axial and torsional stresses, values of E and F are found, which determine μ. The data of the paper relate to tests of metals. It is shown that since both E and F vary with temperature, but according to different laws, μ also varies with temperature. The estimated variation of μ for an 0.49-per-cent normalized carbon steel due to an increase of temperature from 0 to 100° F. is a decrease from 0.267 to 0.231.

The apparatus used was very sensitive. A lateral extensometer was developed that was sensitive to readings of 0.000003 in. with an accuracy tolerance of 3 per cent.

Johnson, A. N., "Direct Measurement of Poisson's Ratio for Concrete," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 1024 (1924).

This paper was intended to describe a method of determining Poisson's ratio, rather than to give any considerable amount of test data. Extensometers of the Marten's mirror type were used for both axial and lateral strains. Two mirrors, arranged to rotate in opposite directions to compensate for movements of the entire test specimen, were used in each instrument. The contact points of the instrument rested in small holes drilled in a steel shoe, curved to fit the surface of the test cylinder.

With the mirror extensometers used it was possible to read axial unit deformations to 0.0000025 and lateral unit deformations to 0.000002 in. per inch.

A few test results are given for $4\frac{1}{2}$ by 9-in. cylinders of mortar and concrete. In all cases, both the longitudinal and lateral stress-strain curves followed the initial tangent up to loads generally one-fifth or more of the ultimate load. From this it is seen that Poisson's ratio was constant for these lower stresses. Values of Poisson's ratio within the limit of proportionality of the material are as follows:

	POISSON'S RATIO
1:2 mortar, age 2 months	0.143 to 0.166
1:2 " " 13 "	0.138 to 0.155
1:2:3 concrete, age 12 months	0.130 to 0.160
1:2:4 " " 6 "	0.157 to 0.180
1:2:4 " cores, age 7 years	0.120
1:2:4 " " " 8 "	0.108
1:2:4 " " " 12 months	0.136

The above mortars varied in compressive strength from 3400 to 4900 lb. per sq. in. and the concretes from 2300 to 3900 lb. per sq. in.

The author notes the tendency toward lower values of Poisson's ratio with increase in age, but considers that the number of tests are too few to justify conclusions as to the effect of age and mixture.

Richart, F. E., Brandtzaeg, A., and Brown, R. L., "The Failure of Plain and Spirally Reinforced Concrete in Compression," *Bulletin No. 190*, Engineering Experiment Station, University of Illinois, 1929.

The tests were made on 23 cylinders, or short columns, 10 in. in diameter, 40 in. in length, of 1:2.1:2.5 gravel concrete, 28 days old. Five columns were of plain concrete, the others had various amounts of spiral reinforcement. Measurements of axial strains were made with an 8-in. Berry strain gage, while lateral strains were measured with a 4-in. Berry gage and with a special diameter gage, similar in principle to the Berry gage. The precision in unit deformation obtained with the 8-in. Berry gage was about 0.000008, with the diameter gage, 0.00001. The compressive strength of control cylinders made with the columns averaged 2685 lb. per sq. in. Values of Poisson's ratio, obtained from the initial slopes of stress-strain curves, were 0.09 to 0.12 for the plain concrete columns and 0.11 to 0.13 for those with spiral reinforcement.

The value of Poisson's ratio was found to hold practically constant for stresses below about 40 per cent of the compressive strength of the plain concrete specimens. Beyond this a rather rapid increase in the lateral strains caused a corresponding increase in the lateral longitudinal strain ratio, which generally reached 0.5 at 95 to 98 per cent of the ultimate load.

Davis, R. E., and Troxell, G. E., "Modulus of Elasticitty and Poisson's Ratio for Concrete, and the Influence of Age and Other Factors Upon These Values," *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 678 (1929).

The tests relating to Poisson's ratio are divided into two groups: Series 1, to determine the effect of age and richness of mix, and Series 2, to determine the effect of age and repeated applications of stress. The test pieces were 6 by 12-in. cylinders of plain concrete. Lateral and longitudinal strains were measured by the use of mirror extensometers of the type used by A. N. Johnson.[1] It was stated that unit deformations could be measured by this apparatus to one millionth.

SERIES 1.—Three concrete mixes were used, 1:3½, 1:4½ and 1:6, by volume. The aggregates were beach sand and crushed sandstone. All cylinders were made with 1-in. slump. The axial stress-strain curves were practically straight lines at low stresses. The older the concrete and richer the mix, the straighter the stress-strain curve. The lateral stress-strain curves were quite similar, but were frequently slightly concave upward at low stresses. Values of Poisson's ratio at a stress of 800 lb. per sq. in. are found to vary only slightly with richness of mix, but to vary considerably with age, ranging from 0.17 at 40 days to 0.20 at 16 months. For unit stresses varying from 200 to 2000 lb. per sq. in. values of the ratio varied from 0.18 to 0.21, being highest at 200 lb. per sq. in., decreasing as the stress increased to 800 lb. per sq. in. and thereafter increasing slightly.

SERIES 2.—All concrete was of 1:5 mix, with crushed granite aggregate. The water-cement ratio was 1.0 and the average slump 3.2 in. Four groups were tested to failure at ages of 1, 3, 6 and 12 months. Others were loaded to a stress of 1000 lb.

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[1] See page 663.

per sq. in. at ages of 3, 6 and 12 months, and later retested. The effect of age was similar to that of Series 1; Poisson's ratio varying from 0.15 at 1 month to 0.20 at 1 year, at a stress of 800 lb. per sq. in. It also decreased from 0.23 at a stress of 200 lb. per sq. in. to 0.18 at 1000 lb. per sq. in. For retested cylinders the effect of earlier loadings was to increase the value of Poisson's ratio 13 to 19 per cent over the original values.

It was concluded that Poisson's ratio increases with age at a gradually decreasing rate, with a small increase after a year. It is not materially affected by richness of mix or character of aggregate. It is greater for low than for medium stresses. At loads of 800 lb. per sq. in. Poisson's ratio at one month is 0.15 to 0.17, increasing to 0.20 for 1 year or more. Values at lower stresses are somewhat higher than these.

Sturm, R. G., "Physical Properties of Large Concrete Cylinders, Calderwood Dam," Unpublished report, January, 1930.

The tests described were planned by J. P. Crowdon and R. L. Templin with the approval of J. W. Rickey of the Aluminum Company of America, and carried out under the direction of D. E. Parsons and A. H. Stang of the Bureau of Standards.

Four groups of test cylinders were made from concrete being placed during construction of Calderwood Dam in Tennessee. Each group contained six 24 by 48-in. concrete cylinders, six 8 by 16-in. and six 6 by 12-in. mortar cylinders. All aggregate was of crushed stone, a hard dense arkose of sizes 0 to ⅜ in. and 3 to 6 in. Pieces larger than 6-in. size were removed in making large cylinders. The concrete cylinders were vibrated and the mortar cylinders rodded in accordance with the Society's standard method. The 24 by 48-in. and 8 by 16-in. cylinders were cured in water until 14 days old, then left outdoors until shipped to the Bureau of Standards for testing at the age of 4 to 5 months.

Longitudinal strains were measured on 32-in. gage lengths by attached 0.001-in. Ames dials and on 2-in. gage lengths by a Whittemore strain gage with 0.0001-in. dial. Lateral deformations were measured by use of an attached "plate ring" extensometer, using a 0.0001-in. "Last Word" dial. Check readings were taken by use of a steel "girdle band" placed over strips of lubricated aluminum foil encircling the cylinder and also using a 0.0001-in. "Last Word" dial. Mean values of Poisson's ratio were found to be 0.15 for the 24 by 48-in. concrete cylinders and 0.17 for the 8 by 16-in. mortar cylinders.

McMillan, F. R., "Shrinkage and Time Effects in Reinforced Concrete," *Studies in Eng. No. 3*, University of Minnesota, 1915.

Measurements were made on longitudinal and lateral gage lengths on a reinforced concrete slab beam by means of an 8-in. Berry strain gage. The readings at the compression face of the beam were quite satisfactory; those at the tension face in which all readings were taken on reinforcing steel naturally involved some uncertainties and were not very consistent. Readings of strains on the compression face during a long-time test of this beam of 1:2:4 concrete showed a value of Poisson's ratio of 0.18 at midspan and 0.20 at the one-quarter point of the span.

GENERAL SUMMARY

The principal data of the various tests heretofore described are summarized in the accompanying Table I. It is quite difficult to estimate the relative weight that should be attached to the various test data in view of precision of apparatus

TABLE I.—SUMMARY OF DATA ON POISSON'S RATIO FOR CONCRETE.

Reference	Concrete Mixture	Kind of Aggregate	Age of Test	Type of Test Piece	Unit Stress Used, lb. per sq. in.	Poisson's Ratio
Talbot	1:2:4	Sand and limestone	60 days	12 by 10-ft. column	Early loads	0.10 to 0.18
Withey	1:2:4	Sand and limestone	50 to 60 days	10 to 12-in. by 10 ft. plain column	$\frac{1}{4}$ Ultimate strength	0.10 to 0.14
	1:2:3$\frac{1}{2}$	Sand and limestone	50 to 60 days	10 to 12-in. by 10 ft. reinforced column	$\frac{1}{4}$ Ultimate strength	0.11 to 0.19
	1:3:6	Sand and limestone	50 to 60 days	10 to 12-in. by 10 ft. reinforced column	$\frac{1}{4}$ Ultimate strength	0.08 to 0.20
	1:1$\frac{1}{3}$	Sand and limestone	50 to 60 days	10 to 12-in. by 10 ft. reinforced column	$\frac{1}{4}$ Ultimate strength	0.08 to 0.20
Am. Concrete Inst. Report	1:1$\frac{1}{2}$:3	Sand and gravel	101 to 126 days	21-in. by 9 ft. 4-in. plain column	$\frac{1}{4}$ Ultimate strength	0.21 to 0.28
	1:1$\frac{1}{2}$:3	Sand and gravel	101 to 126 days	21-in. by 9 ft. 4-in. reinforced column	$\frac{1}{4}$ Ultimate strength	0.13 to 0.19
Wrentmore, Brodie and Carey	1:2:4	Sand and limestone	37 to 426 days	4 by 27-in. plain column	400 to 700	0.13 to 0.19
	1:2:4	Sand and limestone	35 to 49 days	4 by 27-in. spiral reinforced column	400 to 700	0.12
	1:2:4	Sand and limestone	343 to 411 days	4 by 27-in. spiral reinforced column	400 to 700	0.14
Johnson	1:2	Sand	2 months 13 months	4$\frac{1}{2}$ by 9-in. cylinder	Initial	0.14 to 0.17
	1:2:3	Sand and gravel	12 months	4$\frac{1}{2}$ by 9-in. cylinder	Initial	0.13 to 0.16
	1:2:4		6 months	4$\frac{1}{2}$ by 9-in. cylinder	Initial	0.16
	1:2:4	....	1 year 8 years 7 years	Cores	Initial	0.11 to 0.14
Richart, Brandtzaeg and Brown	1:2.1:2 5	Sand and gravel	28 days	10 by 40-in. plain column	Initial	0.09 to 0.12
	1:2 1:2.5	Sand and gravel	28 days	10 by 40-in. spiral reinforced column	Initial	0.11 to 0.13
Davis and Troxell	1:3$\frac{1}{2}$	Sand and sandstone	40 days	6 by 12-in. cylinder	800	0.17
	1:4$\frac{1}{2}$	Sand and sandstone	16 months	6 by 12-in. cylinder	800	0.20
	1:6	Sand and sandstone	100 days	6 by 12-in. cylinder	200	0.21
			100 days	6 by 12-in. cylinder	800	0.18
	1:5	Crushed granite	1 month	6 by 12-in. cylinder	800	0.15
			1 year	6 by 12-in. cylinder	800	0.20
	1:5	Crushed granite	1 month	6 by 12-in. cylinder	Loaded to 1000 and retested	0.20
			1 year	6 by 12-in. cylinder	Loaded to 1000 and retested	0.28
Sturm	1:3:3 approx.	Crushed stone (Arkose) 0 to $\frac{3}{8}$ in., 3 to 6 in	4 to 5 months	24 by 48-in. cylinder	Below 1000	0.15
	1:3 approx.	Crushed stone (Arkose) 0 to $\frac{3}{8}$ in	4 to 5 months	8 by 16-in. cylinder	Below 1000	0.17
McMillan	1:2:4	Sand and limestone	1 to 3 months	5$\frac{1}{2}$ by 30-in. by 12-ft. beam	Low	0.18 to 0.20

and care in preparation and testing of specimens. It seems likely that the mirror extensometer apparatus used by Johnson, Davis and Troxell is more accurate than a movable gage of the Berry type. However, there is no object in great precision of measurement if companion test specimens show large differences in the property measured.

There seems to be some agreement in the test data as to the variation of Poisson's ratio with age, richness of mix and intensity of stress. The tests by Davis and Troxell are quite consistent in showing a small increase in Poisson's ratio as the age of the concrete increases from 1 month to 1 year. This agrees, with one exception, with the results of tests by Wrentmore, Brodie and Carey. Johnson's tests, which seem to indicate a decrease in the ratio with age, are too few to be conclusive.

None of the tests show any particular effect of richness of mix upon the value of Poisson's ratio, nor are there sufficient data to show that the character of the aggregates used were of any significance in this respect.

Johnson's data indicate that Poisson's ratio is a constant up to a stress that may be called the proportional limit for the material. This limit is reached at about the same stress for both axial and lateral stress-strain curves. This seems logical and is in accord with the conclusions of Sturm, Richart, Brandtzaeg and Brown. However, Davis and Troxell, using great refinement of apparatus and technique, find a decrease in Poisson's ratio as the stress increased to about 800 lb. per sq. in. and a gradual increase thereafter. A similar phenomenon was noted incidentally by Wrentmore, Brodie and Carey. Since the strains measured at these low stresses are very small and any instrumental error will therefore be relatively large, the actual behavior of the material is difficult to determine. The variation noted by Davis and Troxell between values of the ratio at stress of 200 and 800 lb. per sq. in. is not relatively great and probably of less importance than the effect of a repetition of loading. Since repetitive loading is known to straighten out the stress-strain curve for concrete over the range of loading, it might be expected that Poisson's ratio would become more nearly constant over that range. The tests by Davis and Troxell, however, indicate that Poisson's ratio merely becomes greater for concrete under repeated loads, but retains its characteristic variation with intensity of stress.

There seems to be agreement in the conclusion that at stresses approaching the ultimate strength, the ratio of lateral to axial strain increases rapidly. Values of the ratio of 0.5 near the ultimate load, which would indicate a zero volume change of the test piece, are evidently indicative of internal splitting of the material.

Considering the range of materials and test methods included in the foregoing tests, the values found by the various investigators seem to be in reasonable agreement. More comprehensive tests are still needed to establish general laws governing the variations noted and to show the underlying cause of such phenomena.

APPENDIX XIII

A SUMMARY OF INVESTIGATIONS OF VOLUME CHANGES IN CEMENTS, MORTARS AND CONCRETES PRODUCED BY CAUSES OTHER THAN STRESS

By Raymond E. Davis[1]

Introduction

Neat cements, mortars, and concretes not only possess the property of changing their volumes with increases or decreases in temperature, but in common with other granular materials also possess the property of changing their volumes with variations in moisture conditions. This is true not only during early life when the hardening process is most actively in progress but for all time so long as the particles of the mass are in the process of physically or chemically absorbing or giving up moisture.

While it has long been recognized that these volume changes were actually taking place in all concrete structures and not a few investigators in this country and abroad have observed and reported upon these volume-change phenomena, only recently has it come to be generally appreciated that permanency is affected not so much upon mere strength and rigidity as upon volume changes which are continually in progress within the mass. Many of the examples of slow, progressive failure of mortars and concrete can only be ascribed to this cause, and it seems safe to say that the property of expanding as water is absorbed or as the temperature increases and of shrinking as mositure is given off or the temperature is lowered is the greatest single factor at work in the disintegration of our concrete structures.

The following summary has been prepared with a view of bringing together the results of what are considered to be some of the more important investigations having to do with volume changes produced by causes other than stress. First, changes due to variations in temperature are summarized. Second, volume rhanges as affected by moisture conditions are reviewed. And third, a bibliogcaphy of literature on the subject is given.

Volume Changes Due to Variations in Temperature

Factors which might be expected to influence the magnitude of volume changes in mortars and concretes due to variations in temperature are:

1. Richness of mix;
2. Kind of cement;
3. Character of aggregate;
4. Water-cement ratio;
5. Age;
6. Moisture content;
7. Temperature;
8. Alternations of high and low temperatures.

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It is frequently considered that 0.0000055 per 1° F. is a sufficiently exact value of the coefficient of expansion of mortars and concretes within the normal range of atmospheric temperatures. However, tests indicate that the coefficient varies within a range between 0.000004 and 0.000009 per 1° F. depending upon a number of the factors listed above. The results of different investigators are far from being consistent for reasons which are not always apparent because of lack of detailed information concerning the conditions surrounding the tests.

TABLE I.—THERMAL COEFFICIENT OF EXPANSION OF CONCRETE.

Material	Coefficient of Expansion per 1° F.	Authority
Neat cement	0.000 006 8	Meier
Neat cement	0.000 008 1	Meier
Neat cement	0.000 007 9	Adie
Neat cement	0.000 005 9	Bouniceau
Neat cement	0.000 007 6	Hyatt
Neat cement	0.000 007 8	Hyatt
Neat cement	0.000 007 0	Keller
1:3 Mortar	0.000 006 6	Bouniceau
1:1 Mortar	0.000 006 1	Keller
1:2 Mortar	0.000 005 6	Keller
1:4 Mortar	0.000 005 8	Keller
1:6 Mortar	0.000 005 1	Keller
1:8 Mortar	0.000 005 3	Keller
1:2:4 Bedford limestone concrete	0.000 005 5	Pence
1:2:4 Kankakee limestone concrete	0.000 005 6	Pence
Granite (average)	0.000 004 5	Bouniceau, Adie, Hurst, Dana
Limestone (average)	0.000 005 1	Bouniceau, Dana, Pence
Marble (average)	0.000 004 2	Bouniceau, Adie, Ganot
Sandstone (average)	0.000 006 9	Haswell, Ganot, Dana, Adie, Thurston

Table I gives thermal coefficients of expansion determined by Keller and also those included in a review by Shitkewitsch (**19**)[1] for several neat cements, mortars, concretes and building stones.

In Table II are summarized the results of tests by Hatt (**50**) which show the variation of the coefficient of thermal expansion as affected by the brand of cement.

TABLE II.—THERMAL COEFFICIENT OF EXPANSION FOR VARIOUS NEAT CEMENTS (HATT).

	THERMAL COEFFICIENT OF EXPANSION PER 1° F.	
CEMENT	AGE, 4 MONTHS IN AIR, RANGE, 50 TO 73° F.	AGE, 2 MONTHS IN WATER, RANGE, 52 TO 90° F.
No. 1	0.000 009 6	0.000 009 4
No. 2	0.000 009 4	
No. 3	0.000 009 2	0.000 008 7
No. 4	0.000 009 0	
No. 5	0.000 008 9	
No. 6	0.000 008 3	
No. 7	0.000 008 5	0.000 008 5

Other results obtained by Hatt (**50**) for concretes of various mixes, ages, and storage conditions, given in Table III, indicate that the thermal coefficient of expansion increases with an increase in temperature.

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[1] The boldface numbers in parentheses refer to the reports and papers given in the list of references appended hereto.

Tests made by Davis and Troxell (56) at the University of California on a 1:4 mix, the aggregate consisting entirely of granite for which the temperature range was between 39 and 125° F. showed no marked variation in the coefficient with age or with moisture conditions, and the variation with temperature was insignificant. The values of the thermal coefficient of expansion as determined by these tests are shown in Table IV.

TABLE III.—THERMAL COEFFICIENT OF EXPANSION OF CONCRETE (HATT).

	Specimen	Mix	Age in Months	Condition	Range in Coefficient of Expansion per 1° F.	Temperature Range Deg. Fahr.
Group 1.....	6 by 8 by 48-in. beams	1:1½:3	2	Oven dry.....	0.000 004 0 to 0.000 006 2	65 to 150
Group 2.....	4 by 7 by 48-in. beams	1:2 3	2	Wet immersed	0.000 004 0 to 0.000 005 6	45 to 95
Group 3.....	4 by 7 by 48-in. beams	1:2:3½	9	Air dry.......	0.000 004 5 to 0.000 005 7	25 to 75
Group 4.....	4 by 7 by 48-in. beams	1:2:3	2	Air dry.......	0.000 004 9 to 0.000 007 0	20 to 95

TABLE IV.—THERMAL COEFFICIENT OF EXPANSION OF 1:4 GRANITE CONCRETE (DAVIS AND TROXELL).

CONDITION	THERMAL COEFFICIENT OF EXPANSION PER 1° F. AT AGE OF 7 WEEKS	 AT AGE OF 4 MONTHS
Immersed in water...........	0.000 004 5	0.000 004 1
In dry air...................	0.000 003 8	0.000 003 9

A second series of tests by Davis and Troxell (56) including both mortars and concretes in lean and rich mixes were made with sand and gravel as the aggregates, two water-cement ratios being employed. Half of the specimens of each group were kept continuously wet, and the remaining specimens were stored in dry air. Tests were made at ages of 6 weeks and 4 months over a temperature range from 40 to 130° F. The results of these tests which are given in Table V make it appear that the coefficient for wet concrete is slightly greater than that for dry, but that variation in age, richness of mix, and water-cement ratio have little effect upon the coefficient.

TABLE V.—THERMAL COEFFICIENT OF EXPANSION OF MORTARS AND CONCRETES (DAVIS AND TROXELL).

	Mortar Mixes	Concrete Mixes	Average for Mortar and Concrete Mixes
Average for wet storage..................................	0.000 004 76	0.000 004 95	0.000 004 86
Average for dry storage..................................	0.000 004 68	0.000 004 43	0.000 004 55
Average for 1.31 Water-cement ratio......................	0.000 004 72	0.000 004 75	0.000 004 74
Average for 1.89 Water-cement ratio......................	0.000 004 73	0.000 004 66	0.000 004 70
Average for age 6 weeks	0.000 004 79	0.000 004 73	0.000 004 76
Average for age 4 months	0.000 004 70	0.000 004 69	0.000 004 70
Average for 1:3 Mix	0.000 004 78	0.000 004 62	0.000 004 70
Average for 1:8 Mix......................................	0.000 004 59	0.000 004 81	0.000 004 70

The results of a third series of tests by Davis and Troxell made on gravel concrete of several mixes and two consistencies are given in Table VI. The thermal coefficient of expansion was determined between the temperatures of 15 and 130° F., first at the age of 9 weeks, the specimens having been stored in dry air at the age of 16 days. These tests indicate that the thermal coefficient of expansion is somewhat lower for lean mixes than for rich ones and is slightly less for wet mixes than for dry ones.

To determine the effect of character of aggregate upon the thermal coefficient of expansion Davis and Troxell made a fourth series of tests upon six groups of specimens, the groups varying from one another only in the character of the fine and coarse aggregate, and being alike in all other respects including the gradation of the fine and coarse aggregate. The aggregates employed were gravel, quartz, metamorphic sandstone, granite, basalt, and limestone, each of these being used in a 1:4½ mix. After damp curing for 16 days the specimens were continuously stored in dry air. At the age of 9 weeks the thermal coefficient of expansion was determined between the temperatures of 15 and 130° F. Thereafter, half the specimens of each group were stored continuously in dry air at 70° F. and the remainder were subjected to 100 cycles of temperature ranging from 15 to 130° F. when the coefficient of thermal expansion was again determined for all of the specimens. The effect of the character of aggregate upon the coefficient of thermal expansion is indicated by the results shown in Table VII where it is seen that the coefficients range from 0.0000038 for limestone concrete to 0.0000066 for quartz concrete.

TABLE VI.—THERMAL COEFFICIENT OF EXPANSION AS INFLUENCED BY RICHNESS OF MIX (DAVIS AND TROXELL).

MIX	THERMAL COEFFICIENT OF EXPANSION PER 1° F.	
	2-IN. SLUMP	6-IN. SLUMP
1:3	0.000 006 44	0.000 006 39
1:4½	0.000 006 00	0.000 005 81
1:6	0.000 005 80	0.000 005 56

TABLE VII.—EFFECT OF CHARACTER OF AGGREGATE UPON THERMAL COEFFICIENT OF EXPANSION (DAVIS AND TROXELL).

KIND OF AGGREGATE	COEFFICIENT OF EXPANSION PER 1° F.
Quartz	0.000 006 6
Sandstone	0.000 006 5
Gravel	0.000 006 0
Granite	0.000 005 3
Basalt	0.000 004 8
Limestone	0.000 003 8

At the age of 23 weeks the coefficient of those specimens continuously stored at 70° F. averaged 3.5 per cent greater than for corresponding coefficients at the age of 9 weeks, and the coefficients for those specimens which had been subjected to 100 cycles of alternating temperature averaged 14.1 per cent lower than corresponding coefficients for the specimens which had been stored continuously in air at 70° F.

The results of all tests by Davis and Troxell indicate that within the normal range of atmospheric temperatures the thermal coefficient of expansion for a given concrete is fairly constant.

Norton (12), at the Massachusetts Institute of Technology, has investigated the effect of high temperatures upon the thermal coefficient of concrete, the specimens being 6-in. and 10-in. cubes, and the heat being supplied by placing the cubes in an electric furnace. The results of these tests, which are shown in Table VIII, make it appear that the coefficient increases slightly up to about 575° F., but becomes smaller at higher temperatures. It is stated that at about 1500° F. the thermal coefficient of expansion became zero, and above that temperature it took on a negative value. Further, the cubes heated to 1500° F. did not return to their original dimensions upon cooling but retained an expansion of about 75 per cent of their maximum change.

TABLE VIII.—THERMAL COEFFICIENT OF EXPANSION AT HIGH TEMPERATURES (NORTON).

TEMPERATURE, DEG. FAHR.	MEAN THERMAL COEFFICIENT OF EXPANSION PER 1° F.
72 to 360	0.000 004 5 to 0.000 006 0
72 to 750	0.000 005 0 to 0.000 006 0
72 to 1090	0.000 004 5 to 0.000 005 0
72 to 1600	0.000 003 5 to 0.000 004 2

The results of a study of the data just presented and also of information contained in the numerous references given in the bibliography lead to the following conclusions:

1. Within normal atmospheric temperatures all mortars and concretes expand upon heating yet contract upon cooling.

2. The thermal coefficient of expansion per 1° F. for neat portland cement varies somewhat with the brand. The tests here reviewed indicate that the coefficient varies between the limits 0.0000083 and 0.0000096. The thermal coefficient of expansion for neat cement is appreciably greater than for a normal cement mortar and concrete using any of the aggregates commonly employed.

3. The thermal coefficient of expansion for both mortars and concretes is somewhat greater for a rich mix than for a lean one, the variation in the coefficient being dependent not only upon the mix but upon the character of the aggregate. Some tests on gravel concrete indicate that the coefficient is approximately 6 per cent greater for a 1:3 mix than for a 1:6 mix.

4. The type of aggregate has a marked effect upon the thermal coefficient of expansion, the coefficient being nearly twice as great for an aggregate composed entirely of crushed quartz as for an aggregate composed entirely of crushed limestone. Some tests made upon concrete of a 1:4½ mix identical in all respects except with regard to the character of the aggregate gave the following coefficients:

Quartz	0.000 006 6
Sandstone	0.000 006 5
Gravel	0.000 006 0
Granite	0.000 005 3
Basalt	0.000 004 8
Limestone	0.000 003 8

5. It appears that the thermal coefficient of expansion of concrete when wet is slightly higher than for the same concrete when air dry. In some cases this variation may be as much as 5 per cent.

6. Within the normal range of atmospheric temperatures there seems to be no appreciable variation in the thermal coefficient of expansion.

7. There seems to be no appreciable variation of the thermal coefficient of expansion with the water-cement ratio or with the consistency of the mix.

8. There is some evidence that the thermal coefficient of expansion, at least for some mixes, for a time increases slightly with age but thereafter seems to remain practically constant. In some tests reported, this increase amounted to approximately 5 per cent between the ages of 2 and 6 months.

9. The effect of alternations of high and low temperatures within the atmospheric range seems to be to decrease the thermal coefficient of expansion. One hundred alternations between 15 and 130° F. have decreased the coefficient 14 per cent from the values obtained by observations upon identical concretes of the same age stored continuously at 70° F.

VOLUME CHANGES DUE TO VARIATIONS IN MOISTURE CONDITIONS

Important factors which may be expected to influence the magnitude of volume changes in mortars and concretes produced by the hardening process or effected by variations in moisture conditions which take place with time are:

1. Composition and fineness of the cement;
2. Proportions of mix;
3. Type and gradation of aggregate;
4. Admixtures (lime, clay, etc.);
5. Consistency of mix;
6. Moisture conditions;
7. Age at first observation;
8. Length of period of observation;
9. Size and shape of the mass;
10. Method of mixing and placing, and absorptiveness of molds;
11. Amount and distribution of reinforcement.

Effect of Composition and Fineness of Cement:

Tests by Bates (25) of the United States Bureau of Standards were made on neat cement and 1:3 standard sand mortars using (1) ten different brands of cement as received, (2) the same brands reground to increase their fineness, and (3) adding to both the normal and the reground cements 2.5 per cent of SO_3 in the form of gypsum. Table IX gives the average expansion for each group which occurred during an interval of 13 weeks when the specimens were immersed in water. It appears that the finer the cement the larger the volume change. The addition of gypsum produces a marked increase in expansion.

TABLE IX.—EFFECT OF COMPOSITION AND FINENESS OF CEMENT UPON EXPANSION (BATES).

	PERCENTAGE EXPANSION OF NEAT CEMENT BARS	PERCENTAGE EXPANSION OF 1:3 MORTAR BARS
Normal cement	0.076	0.012
Reground cement	0.085	0.013
Normal cement plus 2.5 per cent SO_3	0.154	0.028
Reground cement plus 2.5 per cent SO_3	0.121	0.017

Hatt (55) at Purdue University made tests on 2 by 2 by 24-in. bars of six brands of portland cement. The specimens were stored in water for 10 days and in air for 4 years. The maximum contractions occurring in air storage varied from 0.12 to 0.23 per cent. There was little further contraction after one year.

White (14) at the University of Michigan has conducted an extensive series of tests over a long period of years upon 1 by 1 by 4-in. bars composed of both neat cements and 1:3 cement mortars. He has observed that neat-cement bars hardening under water for one year expand from 0.07 to 0.15 per cent, depending upon the cement. Similar neat-cement bars hardening in air for one year exhibit contractions varying from 0.18 to 0.34 per cent. He reports that mortar bars of 1:3 mix hardened under water for one year expanded from 0.01 to 0.05 per cent, whereas corresponding mortar bars hardened in air for one year contracted from 0.06 to 0.09 per cent.

Tests by Davis at the University of California on several brands of portland cement, all of approximately the same fineness, using a 1:2:3 concrete, indicate that among the cements tested there was no large variation either in the contraction during the period of air drying or in the expansion during the period when the specimens were stored continuously under water.

Conclusions.—The following conclusions in respect to composition and fineness of cement have been drawn:

1. Neat cement mortars and concretes when stored in air during the hardening process shrink for a considerable period of time, and when stored under water during the hardening process expand for a considerable period of time.

2. It appears that with specimens in the form of neat-cement bars, the brand of cement and the fineness of grinding have an appreciable effect upon the volume changes both in the shrinkage which occurs during air storage and in the expansion which occurs during water storage. In one series of tests at the age of one year the expansion among the several cements varies from 0.07 to 0.15 per cent, and similarly contraction among the several cements varies from 0.18 to 0.34 per cent.

3. The finer the cement the larger the expansion accompanying water storage both for neat-cement and for 1:3 mortar bars. Tests indicate that regrinding may increase this expansion by at least 10 per cent.

4. The chemical composition of the cement may exert a marked influence upon volume changes. A high gypsum content is undesirable since it materially increases the expansion under conditions of moist storage. Tests indicate that the addition of 2.5 per cent of SO_3 in the form of gypsum may double the expansion of a given cement.

5. The indications are that among normal portland cements (not including the high-early-strength portland cements for which no data are available), the volume changes which will ultimately take place in a normal concrete are not greatly different for one cement than for another. That is, for cements of the same fineness of grinding which will pass the standard tests for a portland cement, a concrete using one brand exhibits approximately the same volume changes under given conditions as does the same concrete using another brand of cement.

Proportions of Cement and Aggregates:

Other things being equal volume changes are greater for a rich mix than for a lean one.

McMillan (27) from observations on 4 by 5 by 24-in. bars of limestone concrete which were cured two weeks under wet burlap and then were stored 430 days in air found that the contractions measured from initial observations taken at the age of one day varied from 0.055 per cent for a 1:3:6 concrete to 0.066 per cent for a 1:1½:3 concrete.

Tests by Matsumoto (33) at the University of Illinois indicate that a direct relationship exists between the cement ratio and both the expansion in water and the contraction upon oven drying. The results of these tests are given in Table X. It will be noted that the oven dry contraction is 2½ times as great for the 1:1 mix as for the 1:3:6 mix.

TABLE X.—EFFECT OF RICHNESS OF MIX UPON VOLUME CHANGE (MATSUMOTO).

Mix	Percentage Expansion, Wet Storage, 60 Days	Percentage Net Contraction, Air Storage, 58 Days	Percentage Net Contraction, Oven Drying, 29 Days
1:1	0.0124	0.046	0.157
1:2	0.0100	0.049	0.124
1:3	0.0101	0.050	0.108
1:1:2	0.0091	0.036	0.081
1:2:4	0.0055	0.033	0.064
1:3:6	0.0019	0.036	0.062

Tests by Davis and Troxell (56) at the University of California, results of which are given in Table XI, also show greater volume changes for rich mixes than for lean ones. The specimens were 3 by 3 by 40-in. bars of gravel concrete of four different gradations of aggregate. They were cured for 28 days prior to oven drying.

TABLE XI.—EFFECT OF RICHNESS OF MIX AND GRADATION OF AGGREGATE ON VOLUME CHANGE (DAVIS AND TROXELL).

	PERCENTAGE CONTRACTION, WET TO OVEN DRY	
CONCRETE	AGGREGATE OF LOW SURFACE MODULUS	AGGREGATE OF HIGH SURFACE MODULUS
1:2	0.117	0.101
1:3	0.105	0.090
1:4½	0.090	0.080
1:6	0.090	0.068

Similar results were obtained by Pearson (34) at the U. S. Bureau of Standards as indicated in Table XII. Initial observations were made upon these specimens when the concrete was still plastic and observations were continued over a period of 9 weeks. The specimens were 1 by 4 by 24-in. bars.

TABLE XII.—EFFECT OF RICHNESS OF MIX AND ABSORPTIVENESS OF BASE ON VOLUME CHANGE (PEARSON).

Mix	Percentage Contraction at 64 Days	
	On Non-Absorptive Bases	On Dry or Damp Absorptive Bases
Neat cement	0.217	
1 cement : 1 sand	0.123	
1 cement : 2 sand	0.110	0.067 to 0.108
1 cement : 3 sand	0.109	0.064 to 0.067
1 cement : 4 sand	0.094	0.059 to 0.081
1 cement : 5 sand	0.086	0.060 to 0.080
1 cement : 6 sand	0.084	0.054 to 0.063
1 cement : 4 crushed gravel	0.067	0.028
1 cement : 6 crushed gravel	0.050	0.024

Conclusions.—The following conclusions in respect to effect of richness of mix have been drawn:

1. Other things being equal the richer the mix the larger the volume change either as given by the shrinkage when storage is in air or by expansion when storage is in water.

2. The following table gives the average results of several groups of tests on specimens of various mixes kept in dry air for one year:

	CONTRACTION, PER CENT
Neat cement	0.25
1:3 Mortar	0.09
1:6 Concrete	0.07
1:9 Concrete	0.05

3. The expansion subsequent to immersion in water at the age of one day for all normal mortar and concrete mixes is substantially less than the contraction when stored continuously in dry air. On the average the expansion accompanying immersion for a considerable period of time seems to be approximately one-third the contraction of the same concrete when stored in dry air for the same period.

Effect of Type and Gradation of Aggregate:

Numerous investigations have indicated the important influence of type of aggregate upon the volume changes developed in mortars and concretes. It appears likewise that the gradation of aggregate is not without its effect.

Chapman (44) reports tests on 2 by 2 by 24-in. bars to determine the effect of type of fine aggregate upon the contraction of 1:2 mortars and 1:2:4 concretes. The results are shown in Table XIII. The fine aggregates were all of the same gradation and the coarse aggregate for all the concrete specimens was a $\frac{3}{4}$-in. gravel. The values given in the table are contractions which occurred after 7 days in water and one year in air.

TABLE XIII.—EFFECT OF TYPE OF FINE AGGREGATE UPON AIR SHRINKAGE (CHAPMAN).

FINE AGGREGATE (SCREENINGS)	PERCENTAGE CONTRACTION 1:2 MORTAR	 1:2:4 CONCRETE
Conglomerate	0.21	0.075
Trap rock	0.21	0.093
Slag	0.14	0.068
Granite	0.13	0.068
Limestone	0.13	0.062

In further tests, Chapman (44) found that a 1:2 mortar with all particles of the fine aggregate passing a No. 20 sieve removed contracted only 0.12 per cent as compared with a contraction of 0.18 per cent for the fine aggregate without these smaller particles removed.

Tests by McMillan (27) on 4 by 5 by 24-in. bars of 1:2:4 concrete indicate similar variations in the volume changes resulting from the use of different aggregates. After 420 days of air storage the contractions were for sandstone 0.066, for trap 0.063, and for granite 0.035 per cent. Observations were begun at the age of two days, the specimens having previously been covered with wet burlap.

Davis at the University of California determined the effect of type of aggregate upon the volume changes of 3 by 3 by 40-in. bars of a 1:2:3 concrete using a water-cement ratio of 0.90, the gradation of the mixed aggregate being the same for all materials, and the fineness modulus of the mixed aggregate being 5.58. The results of the tests shown in Table XIV demonstrate the small contraction of granite and limestone concretes in comparison with similar gravel and sandstone concretes. Attention is called to the fact that the behavior of a concrete using a given aggregate when cured and stored in air is no criterion of the magnitude of the change in volume which will take place in the same concrete when stored in water. Thus, the contraction in air is greatest for the gravel concrete and least for the quartz concrete, while the corresponding expansion in water is least for the limestone concrete and greatest for the granite concrete. Adding corresponding values of contraction and expansion given in Table XIV it will be observed that the total volume change of expansion plus contraction is least for limestone concrete and greatest for gravel concrete. This should not be construed to mean that all gravel concretes would exhibit a maximum volume change correspondingly large, since obviously behavior in this respect would depend greatly upon the character of the gravel.

TABLE XIV.—EFFECT OF TYPE OF AGGREGATE UPON VOLUME CHANGE (DAVIS).

AGGREGATE	PERCENTAGE VOLUME CHANGE IN 3 MONTHS	
	CONTRACTION IN AIR	EXPANSION IN WATER
Gravel	0.079	0.0074
Sandstone	0.075	0.0055
Limestone	0.039	0.0050
Granite	0.037	0.0131
Quartz	0.036	0.0094

The fact that mortar mixes of given cement ratio are subject to larger volume changes than concrete mixes of the same cement ratio leaves the impression that contractions and expansions are dependent in a measure upon the fineness of the aggregate.

Tests by Chapman (44), previously mentioned, substantiate this view, there being noted a reduction in air contraction when the material passing the No. 20 sieve was removed. There appears to be some evidence that the character of the very fine material passing the No. 200 sieve has a much more marked effect upon volume changes than might be expected. Where this very fine material is composed of silt or clay, which when wet feels soaplike when rubbed between the fingers, there is produced a marked increase in shrinkage of a given concrete as compared with the shrinkage which the same concrete with these fines excluded will undergo under similar conditions. But this does not seem to hold true for correspondingly fine materials of crystalline character, such as stone dust, which materials when wet and rubbed between the fingers feel rough or gritty. In order to determine the effect of the stone dust of a granite aggregate upon shrinkage, Davis and Troxell (56) have conducted tests upon 3 by 3 by 40-in. bars of concrete for which the aggregate was composed entirely of granite below the $\frac{3}{4}$-in. size, and the water-cement ratio was 1.0. In this series were three groups of specimens: one containing fine aggregate with all fines passing a No. 100 sieve removed, one containing fine aggregate in which there was 6 per cent of material passing the No. 100 sieve, and one containing fine aggregate of which 25 per cent passed the No. 100 sieve. The specimens were put through several periods of water soaking, air drying, and oven drying. The tests indicate that the percentage of fine material passing the No. 100 sieve had no appreciable effect either upon the shrinkage in the oven-dry state, or upon the expansion after a prolonged period of immersion.

Conclusions.—The following conclusions in respect to effect of type and gradation of aggregate have been drawn:

1. Variations in type of mineral aggregate have a marked effect upon volume changes of concretes in which the aggregates are incorporated. Sandstone, trap, and gravel concretes may be expected to undergo volume changes 50 to 100 per cent greater than limestone and quartz concretes subjected to similar moisture conditions.

2. Regardless of the type of aggregate it appears that when a concrete is cured and stored by complete immersion in water the expansion while continuing to increase for a long period of time is always very materially less than the contraction of the same concrete when cured and stored in air, but there is a marked difference in the behavior of different aggregates with regard to the contraction in air as compared with corresponding expansion in water. Thus, a granite concrete which is subject to a relatively small air contraction has a high water expansion, while sandstone which has a relatively high water contraction exhibits a relatively low water expansion.

3. The gradation of the aggregate while having a much less pronounced effect upon volume changes than has the mineral character of the aggregate, nevertheless appears to exert some influence on expansion and contraction. Particularly, it seems to be true that if the very fine material of the aggregate, such as that passing say a No. 200 sieve, be of a claylike character, such material influences volume changes to a marked degree, but if it be of angular or crystalline character, such as is the character of stonedust, then the effect upon the volume change is slight.

Effect of Admixtures of Lime, Clay, etc.:

The influence of lime as an admixture upon concretes and mortars as indicated by the expansion of 4 by 4 by 24-in. bars immersed for 24 hours subsequent to 7 weeks of air storage is reported by Scofield and Stinchfield (29). The lime content varied from 0 to 15 per cent of the cement by weight for both mortar and concrete specimens. The expansion accompanying immersion increased with the quantity of admixture, varying from 0.017 to 0.020 per cent for concrete specimens and from 0.019 to 0.022 per cent for mortar specimens. The kind of lime is not reported.

Tests by Davis and Troxell (56) indicate that an admixture of high-calcium hydrated lime into a basic 1:3 cement mortar has no appreciable effect upon the shrinkage. In these tests various amounts of hydrated lime up to an amount equal in volume to that of the cement were employed. After 28 months in dry air storage the contraction for the various groups varied from 0.15 to 0.16 per cent.

A second series of tests by Davis and Troxell, similar to those described in the preceding paragraph, was made to determine the effect of the same lime used as an admixture upon mortars cured in air for 7 months and then stored in water. After a period of more than 3 years, when all changes in length had apparently ceased, there was observed a residual shrinkage of 0.04 to 0.06 per cent, or approximately one-third that which took place in air prior to immersion. While the expansion accompanying immersion was greatest for the mortar with the largest lime content and was smallest for the mortar containing no lime, the difference was not marked.

Tests made by White (14) and by Davis and Troxell (56) to determine the effect of integral waterproofing compounds indicate that of those tested none aided in reducing the volume changes from alternate wetting and drying of cement mortars.

Conclusions.—The following conclusions in respect to effect of admixtures have been drawn:

1. High-magnesium hydrated lime used as an admixture in cement mortars appears to have little effect either upon the shrinkage accompanying air storage or upon the expansion accompanying water storage.

2. In general, the use of integral waterproofing compounds is not effective in preventing or reducing volume changes in concrete.

3. The substitution of a dolomitic or high-magnesium lime for cement in small quantities up to 10 per cent of the weight of the cement reduces the contraction of mortar bars stored in dry air. Similar substitutions of clay for cement, the clay being intimately ground with the cement, indicates that the volume changes increase as the clay content increases.

TABLE XV.—EFFECT OF WATER-CEMENT RATIO ON VOLUME CHANGE (DAVIS AND TROXELL).

Mix	Water-Cement Ratio	Percentage Change in 3 Months	
		Expansion in Water	Contraction in Air
1:4	0.98	0.0184	0.068
	1.07	0.0204	0.072
	1.16	0.0165	0.080
1:6	0.98	0.019	0.064
	1.07	0.019	0.064
	1.16	0.018	0.069

Effect of Consistency of Mix:

McMillan (27) reports a series of tests on 1:2:4 concrete in which the water content varied from 7.75 to 10.0 per cent, the results of which indicate that the shrinkage after 430 days in dry air varied directly with the amount of mixing water and ranged from 0.055 to 0.063 per cent.

Davis and Troxell (56) report two series of tests to determine the effect of consistency of mix upon volume changes, one series being made on mortar specimens and the other upon concrete specimens, part of the specimens of each group being cured and stored in air and the remainder being cured and stored in water. These tests indicate that both for the mortars and for the concretes the larger the water-cement ratio the greater the contraction in air and the smaller the expansion in water. The tests extended over a period of 3 months. It was observed that the differences due to variations in water-cement ratio were materially less for lean mixes than for rich ones. The results of the tests on concrete specimens are shown in Table XV.

Conclusion.—The following conclusion in respect to effect of consistency is drawn:

The contraction of a concrete which is cured and stored in dry air varies with the quantity of mixing water. Between a wet and dry mix, using identical materials, the air contraction may vary 20 per cent or more for rich mixes, but for lean mixes this variation between the shrinkage of wet and dry mixes may not exceed 5 per cent.

Effect of Moisture Conditions:

Hatt (55) has shown that character and length of previous exposure and the resulting condition of the specimen influence later changes. Thus, if during the early life of a concrete it is stored in air for a considerable period of time the shrinkage which occurs during this period is always greater than the expansion which will take place during any subsequent period of water storage. This same property has been observed by Davis and Troxell (56) in gravel and granite concretes, and also by Goldbeck and Jackson (30).

Tests made by Goldbeck and Jackson (30) on two mixes of concrete of both wet and dry consistency, cured for varying periods of time under moist conditions and then stored in dry air, indicate that the length of the initial period of water-curing has no appreciable effect upon the ultimate air shrinkage.

McMillan (27) likewise shows that the ultimate total shrinkage due to air drying is independent of the method of curing or the length of the curing period.

Also Goldbeck and Jackson (30) found that the contraction of concrete in dry air may be greatly retarded by coating the concrete with tar so that the contained moisture does not escape. Specimens water-cured for 13 days, then air-dried for one day, and then coated with tar contracted only 0.003 per cent at the age of 210 days, whereas similar specimens under similar storage conditions but without the coating contracted 15 to 20 times as much.

Davis and Troxell (56) have found that normal variations in atmospheric humidity are sufficient to appreciably change the rate of contraction of bars which have previously been stored in water, or the expansion of bars which have previously been oven dried. When a concrete has reached a state of absorption equilibrium a relatively small change in the humidity of the surrounding atmosphere is sufficient to produce additional volume changes of measurable magnitude.

Effect of Age at Time of First Measurement:

The first measurement to determine volume changes has ordinarily been made after the specimen has acquired sufficient strength to be handled without fear of fracture, which has usually been at the age of 2 days.

Since mortars and concretes expand when stored under water and contract when stored in air, it is obvious that if exactly the right moisture conditions were maintained no volume change whatever would occur. Initial curing under damp burlap during the period prior to the removal from the molds is an attempt to furnish sufficient moisture so that this condition will be realized. When specimens are initially cured in this manner in molds which are themselves rigid and which offer frictional resistance against relative movement of the specimen contained therein, it seems improbable that the change in volume for ordinary mortar and concrete specimens is appreciable between the time when the mass takes final set and loses its plastic properties and the time of the removal of the molds.

In an attempt to determine the early volume changes in mortar mixes, Pearson (34) at the Bureau of Standards observed the behavior of 1 by 4 by 24-in. specimens from the time they were molded. Although attempt was made to eliminate the resistance of the molds to the changes in the mortars it seems probable that the specimens were in a measure restrained. The specimens were cured in air. The tests indicate a pronounced contraction during initial set, but the rate of shrinkage was greatly reduced at 8 to 10 hours. It was observed that little change occurred between 12 and 24 hours, although the shrinkage up to 12 hours was marked. It was concluded that these initial volume changes after the time of final set could be closely controlled within narrow limits by taking the necessary precautions.

Effect of Duration of Tests:

White (14) in a series of tests on 1 by 1 by 4-in. neat cement bars extending over a period of twenty years has found at the end of this period that the contraction for those specimens stored in air was apparently still in progress, while expansion for those specimens continuously stored in water had apparently reached its maximum at an age of about 10 years.

For mortars and concretes where the dimensions of the specimen has been 2 by 2 in. the change in length after a year or two under constant conditions of storage is small in comparison with that developed previously, and the volume changes after 3 years appear to be insignificant.

Effect of Size and Shape of Specimen:

As the size and shape of the test specimen must have a marked effect upon the rate of loss of moisture upon exposure to dry air, or upon the absorption of moisture upon immersion, it is evident that these factors will influence the rate of volume change as well as the total expansion or contraction. Since there is likelihood of larger variations of moisture content within a large mass than within a small one, these variations will tend to produce different volume changes at the faces of the mass than at its center. It appears that there must always be set up, as volume changes take place, stresses part of which are tensile and part of which are compressive in character. It might be expected that these stresses would produce a plastic yielding or flow of the concrete permanently elongating the tensile fibers and shortening the compressive fibers so that in a large, thick mass the ultimate shrinkage might be expected to be considerably less than in a small thin mass. Likewise, under given constant conditions volume changes would continue over a much longer period of time in the case of the large mass than in the case of the small one.

Effect of Method of Mixing and Placing, and Absorptiveness of Forms:

McMillan (27) reports that small variations in density of the mix make no appreciable difference in the magnitude of the changes.

Pearson (34) concludes that the shrinkage of concrete in air may be reduced 25 to 50 per cent when the concrete is cast upon a dry or damp base which is of an absorptive character over that which would be produced in similar concrete cast on a non-absorptive base.

Tests by Davis and Troxell (56) show that for 3 by 3 by 40-in. bars of 1:3 mortar cast in dry, porous, burned-clay molds, the contraction is about 15 per cent less than for similar bars cast in waterproof molds.

Effect of Amount and Distribution of Reinforcement:

When shrinkage occurs in a reinforced, unrestrained structure compressive stresses are developed in the steel and tensile stresses are set up within the concrete. These tensile stresses tend to produce a plastic yielding or flow of the concrete so that, due to stress, there is an elongation of the tensile fibers while at the same time, due to loss of moisture, there is a shortening of these same fibers.

Considère (6) reports the behavior of neat cement and mortar bars half of which were reinforced each with single, round steel bars, and the remainder of which were of plain concrete. The specimens were 1 by 2.4 by 24 in. and the reinforcing was 0.4 in. in diameter. The effect of reinforcing for both specimens stored in water and those stored in air was greatly to reduce the magnitude of volume changes. The results are given in Table XVI.

TABLE XVI.—EFFECT OF REINFORCEMENT UPON VOLUME CHANGE (CONSIDÈRE).

TYPE OF SPECIMEN	PERCENTAGE CHANGE IN LENGTH	
	IN WATER	IN AIR
Neat cement, not reinforced	+0.079	−0.132
Neat cement, reinforced	+0.022	−0.025
Mortar, not reinforced	+0.028	−0.050
Mortar, reinforced	+0.006	−0.010

Matsumoto (33) conducted three series of tests upon 1:2:4 reinforced concrete to determine the effect of steel reinforcing upon the contraction, and to determine the shrinkage stress developed in the steel and in the concrete. The results of these tests are given in Table XVII. The data of this table show that contraction is materially reduced by the introduction of steel, but that high tensile stresses are developed in the concrete. The larger the percentage of reinforcing steel the greater the stress in the concrete. These tests show that the shrinkage stresses in the steel may reach the safe working stress if the percentage of steel is less than 1.5, and that the shrinkage stress in the concrete may exceed the tensile strength of the concrete if the percentage of reinforcement exceeds 1.5.

TABLE XVII.—EFFECT OF REINFORCEMENT UPON VOLUME CHANGE (MATSUMOTO).

	Reinforcement, per cent	Percentage Contraction	Shrinkage Stress, lb. per sq. in.	
			Steel, Compression	Concrete, Tension
Series 1	0.00	0.061	0	0
	3.68	0.017	5 400	190
	6.54	0.012	3 500	240
Series 2	0.00	0.064	0	0
	0.55	0.054	16 400	90
	1.23	0.042	12 500	150
	2.18	0.029	8 500	190
Series 3	0.00	0.064	0	0
	0.55	0.054	19 000	100
	1.23	0.042	15 500	200
	2.18	0.029	12 000	250

In a similar series of tests reported by Goldbeck and Jackson (30), specimens 8 by 8 by 60 in., some of which were plain, some of which were reinforced with 0.6 per cent of longitudinal steel, some of which were reinforced with 1.2 per cent of longitudinal steel, and some of which were reinforced with 1.8 per cent of longitudinal steel, were stored in dry air for 6 months. At the end of this period the bars of plain concrete had contracted 0.35 per cent, whereas the bars containing 1.8 per cent of reinforcing steel had contracted only 0.010 per cent, or less than one-third as much. The calculated stress in the concrete containing the largest percentage of reinforcement was 750 lb. per sq. in., but no cracks were visible. This makes it evident that flow within the concrete must have taken place as the tensile stress therein gradually increased, so that the actual tensile stresses were very much less than the calculated values.

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(A bibliography included in reference (21) above lists several foreign and early articles many of which are not included in the above bibliography. However, an attempt has been made to include those of greater interest in the present review.)

REPORT OF SUBCOMMITTEE XVII ON CONDITIONS AFFECTING DURABILITY OF CONCRETE IN STRUCTURES

Subcommittee XVII of Committee C-9 and Committee 801 of the American Concrete Institute held a joint meeting in Canada, convening at the Chateau Laurier, Ottawa, on September 9, and ending in Toronto, September 18, 1929. After a short preliminary meeting at the Chateau Laurier, the committee proceeded on an inspection tour of 1673 miles in which approximately thirty structures were viewed. By structure is meant a whole development, such as the Montreal Harbor, which comprises concrete built at different times, by various contractors using a number of aggregates and brands of cement and extending over a period of nearly thirty years.

The concrete inspected on this tour was of structures exposed to the elements and consisted of concrete roads, highway bridges, canals and locks, dams and power plants, retaining walls and harbors. In age, these structures varied from new construction to some 33 years old. They are situated in the territory extending from Toronto to Quebec City and the Lake St. John district, north of Quebec City, Canada.

Concrete failures have been and can generally be ascribed to one or more of the following factors: faulty design, insufficient mixing and curing, use of excess water, segregation of the ingredients, frost action on immature concrete, acid and soft water corrosion, sea water and alkali soil water, improper placing, use of insufficient cement, inferior aggregate and possibly inferior cement, but if so, rarely.

The concrete viewed on this tour can be said to have been generally good and much of it was of real high quality. Two of the dams, however, appeared to be disintegrating very rapidly and some concern was felt as to their security. One was of the Ambursen type, built in 1912, the other of the gravity type, built in 1920 and 1921. None of the structures, with the exception of some of the newest, were without blemishes of some kind, and some had many defects which may lead ultimately to local failures within the structures, and for the present detract greatly from their appearance.

In no case could the failures, or partial failures, be attributed to the cement used, nor solely to the aggregate, although in several cases the aggregates may have contributed to a more rapid disintegration once deterioration had set in through other causes. With a

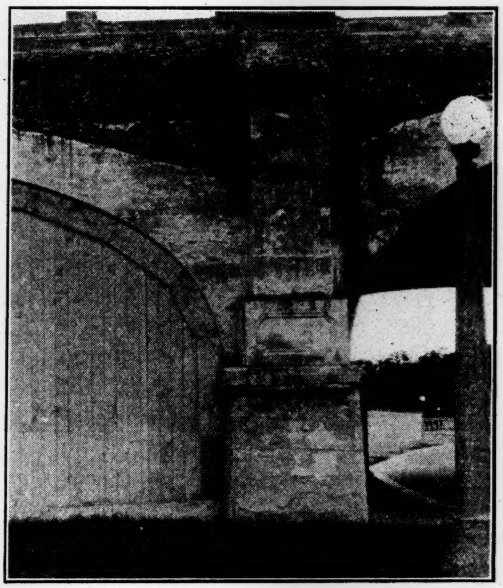

FIG. 1.—A Highway Bridge Built in 1912.

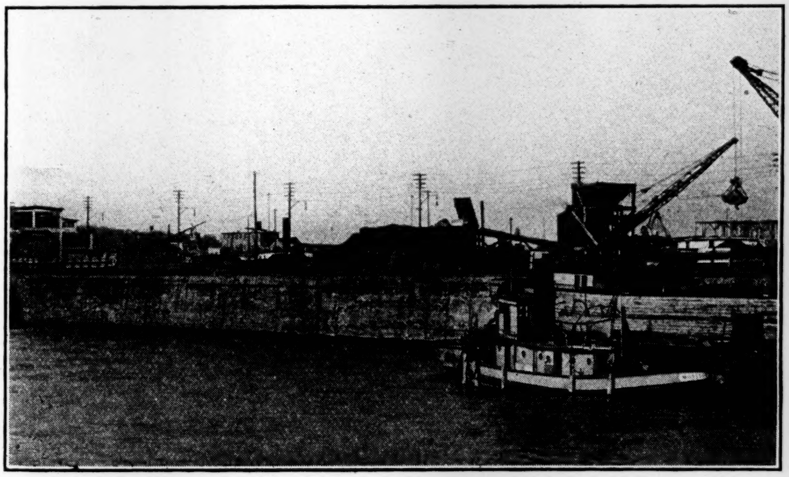

FIG. 2.—A Dock Built in 1902.

single exception, all the failures, whether whole or partial, could be traced to a lack of knowledge of the proper technique of making and placing concrete or to indifference as to what the results would be. The only exception noted was a case where design of the structure may have been a factor.

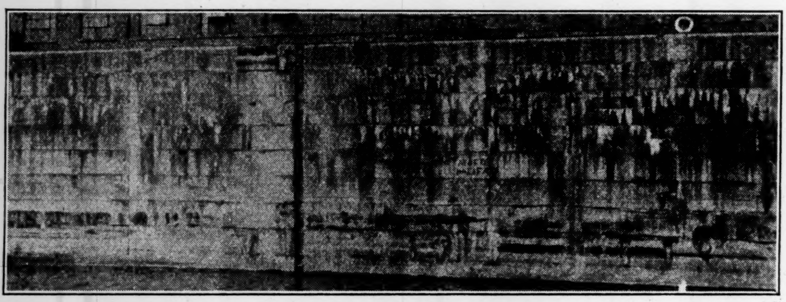

FIG. 3.—Harbor Wall Built in 1911.

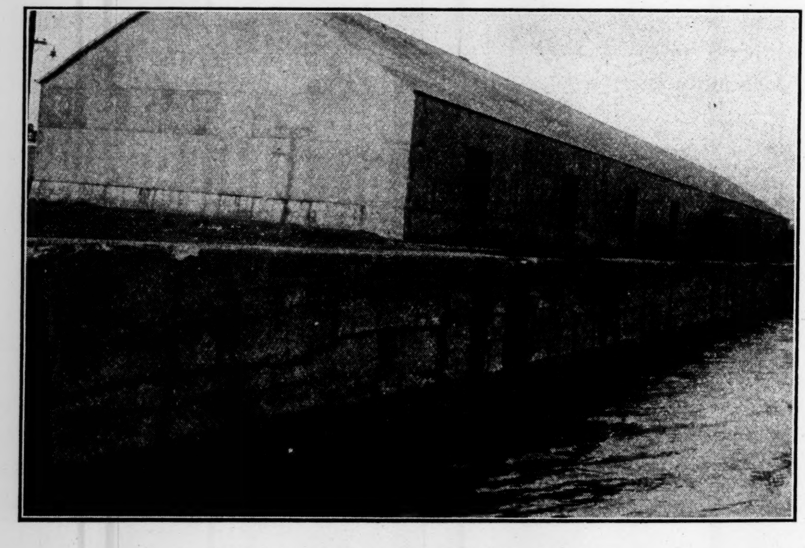

FIG. 4.—Harbor Wall Built in 1915.

One of the oldest structures visited was that of a canal built 30 years ago. This might be said to be in perfect condition with the exception of slight erosion, in spots, at the water line.

The concrete roads viewed on the way were all of good appearance, though some were new and others comparatively new and possibly it was too early for defects to show. The oldest roads encountered were 17 years old. These were in excellent condition and looked as though they might continue to give good service for a long time to come.

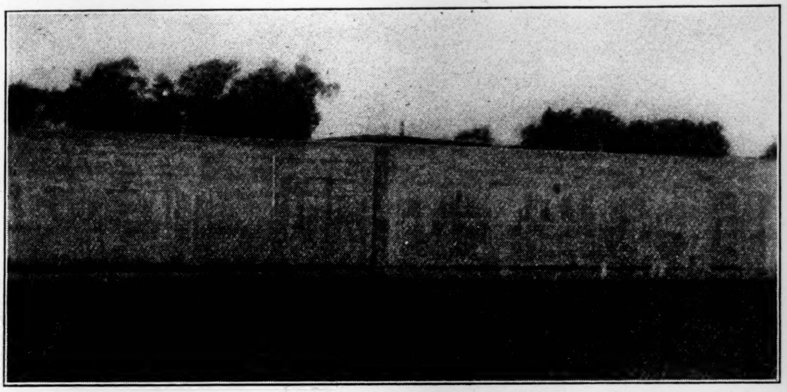

FIG. 5.—Harbor Wall Built in 1928.

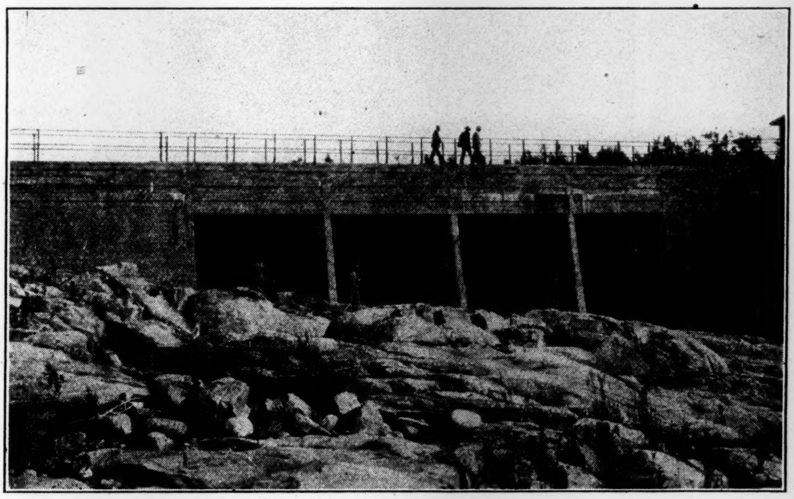

FIG. 6.—Ambursen Dam Built in 1912.

Many photographs were taken of the various defects, near failures, and good concrete.

Figure 1 shows a highway bridge on which has been spent practically half of the original cost in repairs and which will have to be replaced before many years. The causes, as disclosed by available records and from engineers who are familiar with the facts of the

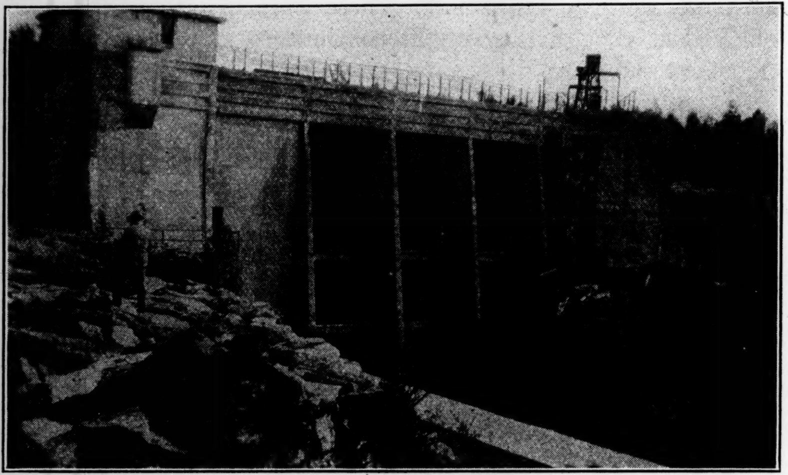

FIG. 7.—Ambursen Dam Built in 1912.

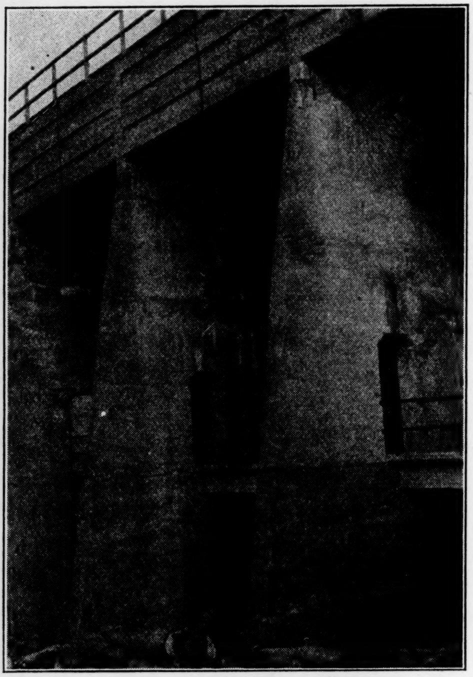

FIG. 8.—Ambursen Dam Built in 1912.

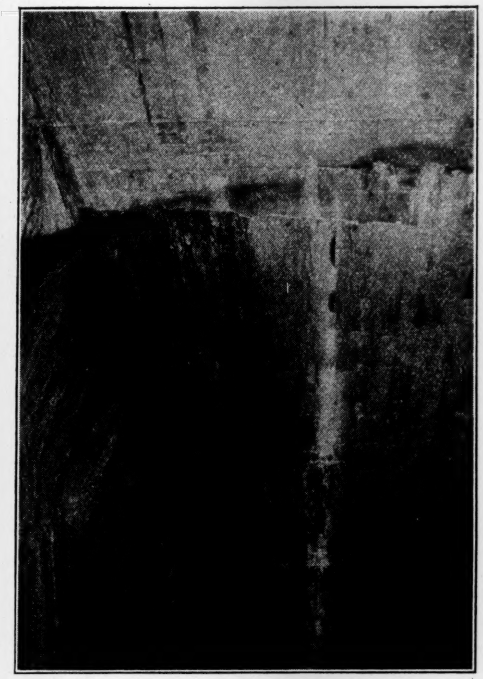

FIG. 9.—Ambursen Dam Built in 1912.

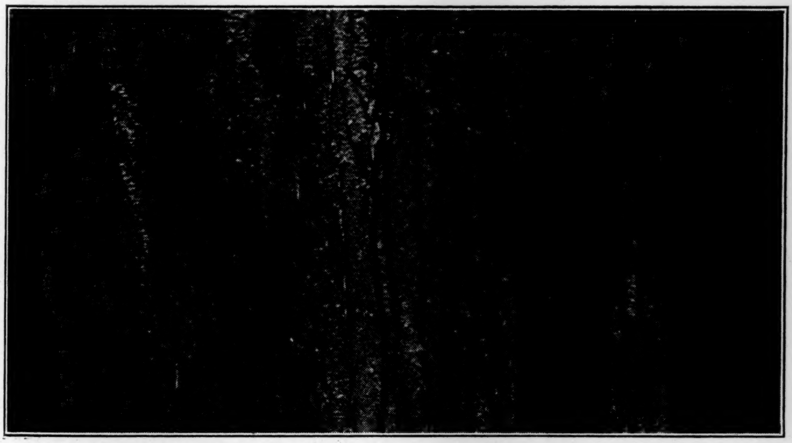

FIG. 10.—Ambursen Dam Built in 1912.

case, are insufficient cement, sloppy concrete, and inferior aggregate. The aggregate was pit-run with a predominance of fine material, a high percentage of dirt and containing much unsound material.

Figure 2 illustrates a work having insufficient cement for the severeness of its exposure, a 1:2.5:5 mix having been used, containing inferior aggregate. The concrete was also poorly placed and possibly improperly designed. The aggregate was a fine sand and crushed limestone containing much shale.

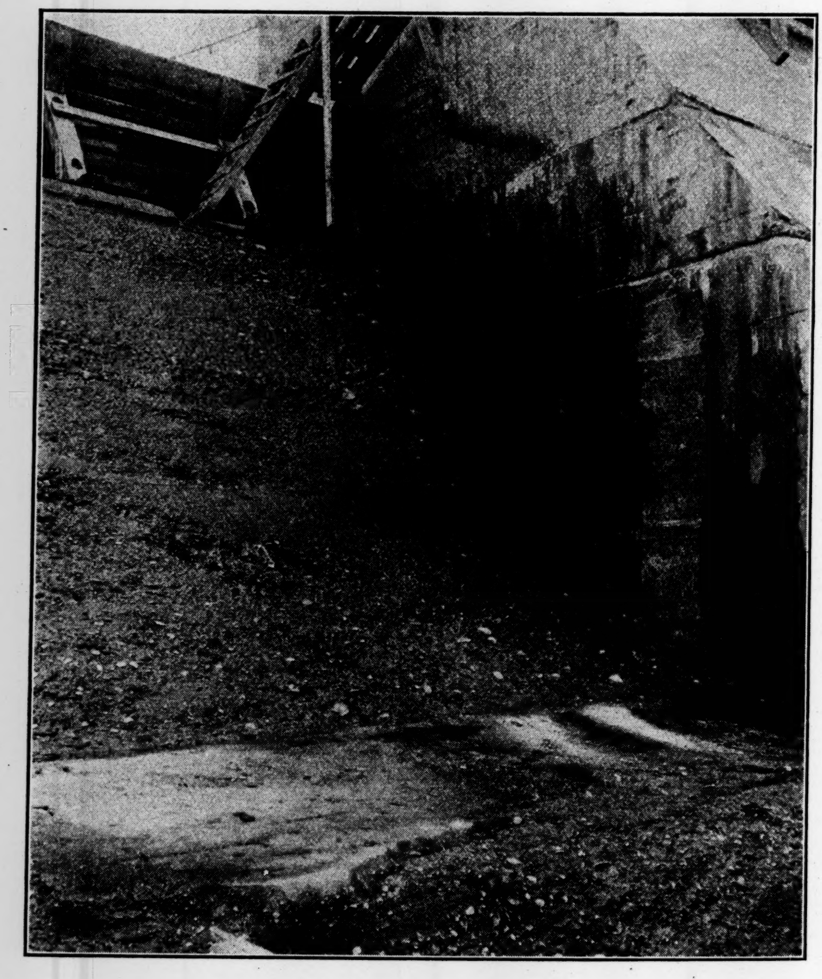

FIG. 11.—Gravity Dam and Power House Built in 1920 and 1921.

Figures 3, 4 and 5 illustrate failure to bond successive layers;

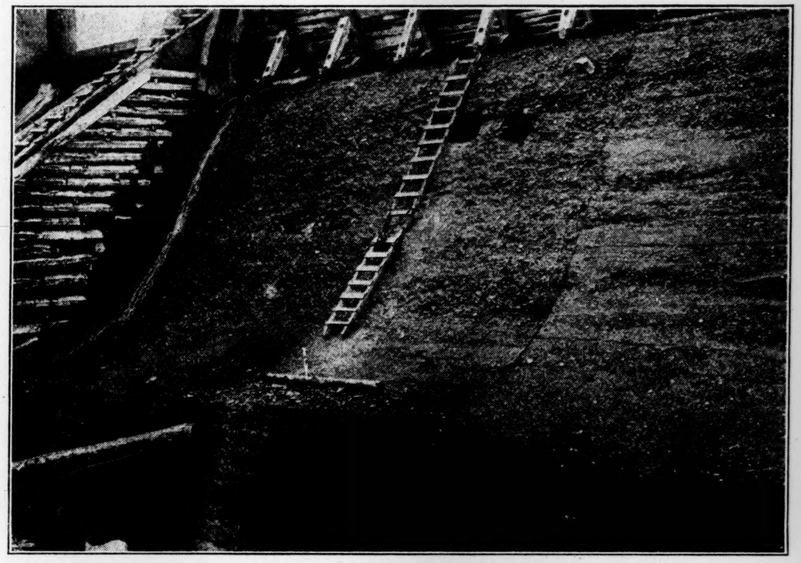

FIG. 12.—Gravity Dam Built in 1920 and 1921.

FIG. 13.—Gravity Dam Built in 1920 and 1921.

otherwise the concrete is good, but marred by the horizontal joints and efflorescence in two cases.

Figures 6 to 10, inclusive, are of an Ambursen dam built in 1912 This dam appears to be in a far advanced state of disintegration where it is in immediate contact with water. In the light of our present knowledge the design would probably be considered faulty in that no adequate provision was made for expansion and contraction, nor for the bonding of the successive layers. The water, which is very soft, gets in the joints of the slab directly over the buttresses and the construction joints of the successive layers and leaches out the lime from the cement. Figures 9 and 10 show incrustation of calcium carbonate underneath the slab and the sides of the buttresses. The concrete that is not exposed to the percolating water seems to be standing up fairly well.

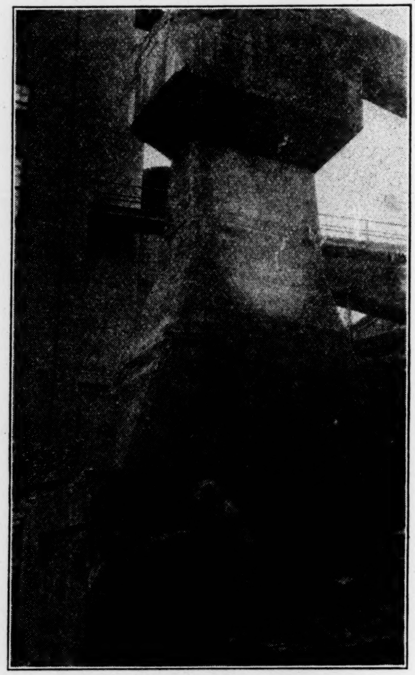

FIG. 14.—An Illustration of Segregation in Concrete Pier, 15 Years Old.

Figures 11 to 13, inclusive, are of a gravity dam and power house built in 1920–1921. The water, which is very soft, is percolating, not only through vertical expansion joints and construction joints of the successive layers of concrete but also, in some places, through the concrete mass. From information received and the appearance of the concrete, the causes for the deterioration are due to insufficient cement, ungraded aggregate, which was pit-run with possibly great variation in the ratio of fine to coarse, and very sloppy concrete, which was evident from the heavy layers of laitance that were to be seen. The aggregate was apparently clean and structurally sound.

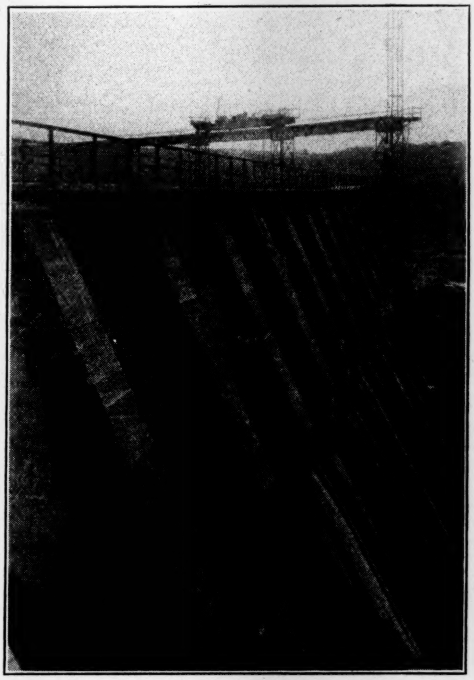

Fig. 15.—Horizontal Joints in Concrete Dam, 15 Years Old.

Figure 14 shows a pier about 15 years old which illustrates segregation—a common defect in placing concrete. The disintegration just below the horizontal joint is a result of water and light material running to the corner of the form. A similar defect can be seen at the extreme top of the pier.

Figure 15 shows other horizontal joints in concrete built about 15 years ago. The water, which in this case also is comparatively soft, follows these horizontal joints and leaches out the lime at that point and thereby subjects these already weak spots to the action of frost.

Figures 16, 17 and 18 illustrate three structures of recent construction in which every care was taken to attain durable concrete.

The concrete was of a quality testing from 3000 to 3500 lb. per sq. in. at 28 days. Each section in these three structures was made without horizontal joints. The engineer in responsible charge of these works required of the contractor of each job that the capacity of his plant be sufficient to cover the whole area of the section in at least 30 minutes so as to permit of a perfect bond of the successive layers. The concrete was required to be of a consistency such that the slump would not exceed 3 in.

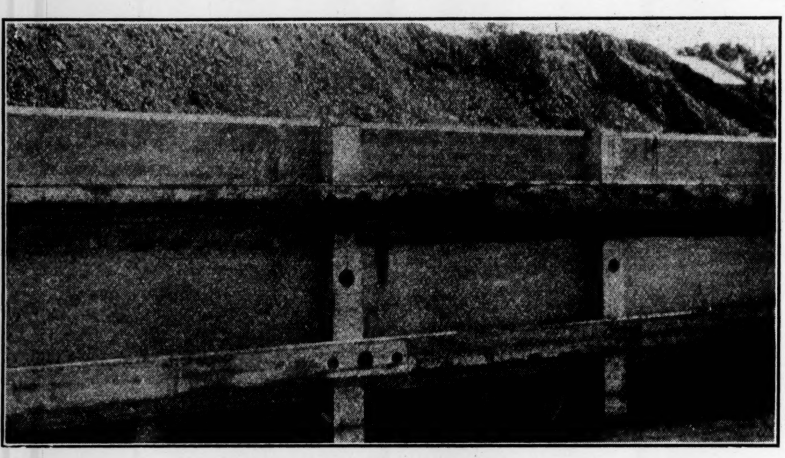

FIG. 16.—Dock Built in 1928.

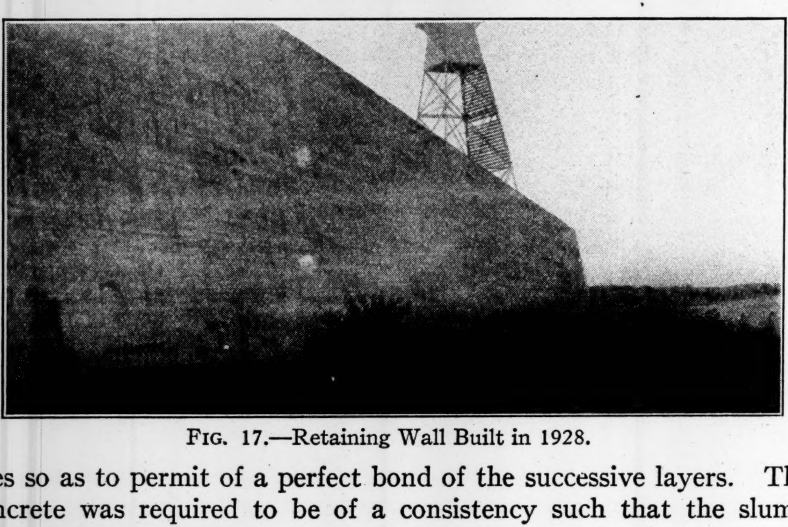

FIG. 17.—Retaining Wall Built in 1928.

The reasons back of the committee's statement that it encountered no cement failures on this tour are that all the structures examined had sufficient good concrete to show that, had the concrete been made into a homogeneous mass equally as good as the best in each structure, there would have been no failures. This, of course, excepts the structures in which, as pointed out above, insufficient cement and inferior aggregate were used. Even in those cases, had the concrete been homogeneous and properly placed, it would have given much better service than it did.

In conclusion, the committee believes that for the structures examined on this inspection tour all of the defects observed could have been avoided by proper attention to four factors: quality of aggregate, quantity of cement, consistency of the mix, and the methods of placing. Further, the committee is of the opinion that all engineers responsible for concrete design and construction should make similar inspection tours in order to study for themselves the common errors of the past so that they may apply their ingenuity to a greater advantage in overcoming them.

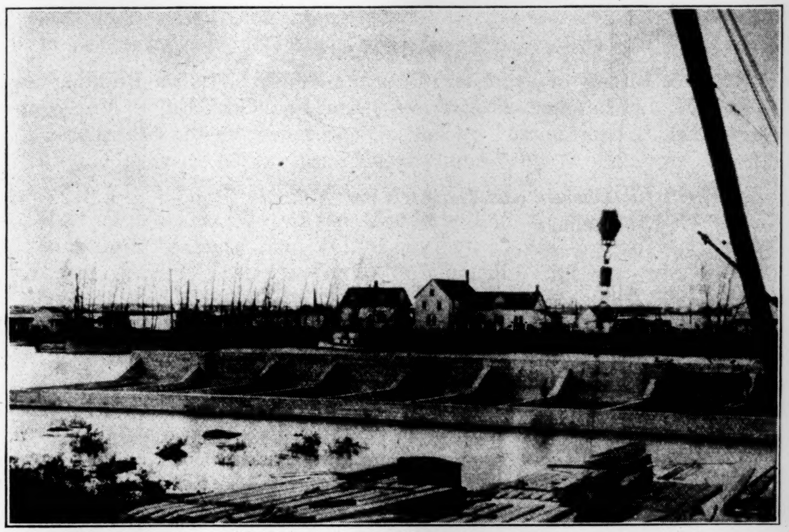

FIG. 18.—Wharf Built in 1928.

The committee feels constrained to point out also the obligation resting upon those in final authority on concrete construction to see that competent men are placed in direct charge of the operation and that they be given the fullest support in their efforts to obtain concrete of the desired quality.

The Bibliography on Deterioration of Concrete, appended hereto, is given for those who wish to enlarge their knowledge on the subject of this report.

Respectfully submitted on behalf of the subcommittee,

EPHREM VIENS,
Chairman.

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Discussion of above article, by T. H. Wiggen, *Transactions*, Am. Soc. Civil Engrs., Vol. 89, p. 743 (1926).

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(15) "Causes of Concrete Pavement Deterioration," by J. S. Bixby, *Engineering News-Record*, Vol. 98, May 19, 1927, p. 810.

(16) "Damage to Cement Structures Caused by Dissolution or Disintegration, and Outline of Means to Prevent Same," by R. Schlyter, Pamphlet, Government Testing Station, Stockholm, 1927.

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(18) "Action of Pure Water on Hydraulic Cements," by Rengade, *Le Ciment*, Vol. 32, p. 370 (1927).

Distilled water falling on halves of briquets first washed surface grains of sand bare in 5 to 12 weeks and then dug out a crater. A specimen made of an aluminous cement withstood attack for 100 weeks. A super-portland cement was next best while lime was poorest. Calcareous Rhone River water had no effect on specimens.

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(20) "Testing and Thawing Frozen Concrete," by A. M. Bouillion, *Mining and County Engineering*, Vol. 72, No. 3, p. 108 (1927); also *Engineering and Contracting*, Vol. 66, p. 69, February, 1927.

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(22) "Rapid Freezing of Stones," by C. C. Wiley, *Proceedings*, Internat. Congress Testing Mats., Vol. 2, p. 280 (1927).

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(23) "Stone Preservation and Decay," by A. F. Laurie, *Journal*, Royal Inst. Architects, Vol. 35, p. 383 (1928).

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(24) "Deterioration of Concrete," by W. Petry, *Tonindustrie Zeitung*, Vol. 52, p. 398 (1928).

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Most damage is caused by H_2SO_4 when combined in sea water or free in natural acid water. Ordinary concrete can be made resistant by using a dense, non-porous aggregate of uniformly sized material. At least 400 kg. of cement per sq. meter must be used. Painting with bitumen is beneficial, and better than covering with cement and clinker. Aluminous cement with 7 to 50 per cent Al_2O_3 is very resistant to $MgSO_4$, but its behavior in presence of Na_2SO_4 is doubtful. Resistance of pozzuolana to corrosion is very great, as is shown by the existence of water mains of this material in good condition today, constructed by the Romans.

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(28) "Comparative Study of Weathering of Rocks Under Different Climatic Conditions," by Blanck and Rieser, *Chemie der Erde*, Vol. 13, pp. 437, 588 (1928).

(29) "Corrosion of Concrete," by C. Hari, *Kogyoshio*, Vol. 16, p. 1340 (1928).

Action of H_2O, CO_2, H_2SO_4, and HCl.

(30) "Requirements for a Durable Concrete as Observed from Structures in Service," by R. B. Young, *Journal*, Engineering Inst. (Canada), Vol. 11, March, 1928, pp. 161, 192; *Engineering Abstracts*, Vol. 37, p. 26 (1928).

(31) "Defects in Reinforced Concrete Beams," by T. D. Sellman, *Concrete and Constructional Eng.*, Vol. 23, No. 8, p. 558 (1928).

Failure due to insufficient cover of reinforcing bars which could with advantage be increased from 1 and ½ in. to 1½ and 1 in., respectively.

32) "Destruction of a Reinforced Concrete Floor Through the Rusting of the Reinforcement" German Reinforced Concrete Association, *Tonindustrie Zeitung*, Vol. 52, No. 68, p. 1380 (1928).

Alterations to a shop revealed reinforced concrete floor finished with hard gypsum plaster (Estrich) covered with linoleum. Settling of building caused the plaster and linoleum to crack perpendicular to reinforcement which it was found was so heavily rusted that entire floor had to be renewed. The occurrence is explained by formation of acid in plaster layer caused by penetration of water during washing of linoleum.

(33) "Some Aspects of Weathering of Building Materials," *Builder* (London), Vol. 135, p. 865 (1928).

Report of lecture given by R. J. Schaffer on causes of decay of building materials, especially limestones and sandstones. Chief among the causes is the crystallization of calcium sulfate resulting from chemical reaction between calcium carbonate and the sulfur gases in the atmosphere. Effect of sea spray is also given, as well as mention of the effect of consistency on the durability of concrete, and the possibility of impregnating concrete with bitumen.

(34) "Investigations on Reinforced Concrete Structures Close to the Sea in the Dutch Indies," by C. Wolterbeck, *Proceedings*, Internat. Congress

Testing Mats., Part II, p. 172 (1927); *Zement*, Vol. 17, No. 2, p. 65 (1928).

Investigation by the Dutch Government Commission. Concludes that the primary cause of the failures investigated was the rusting of reinforcement which, accompanied by expansion, caused cracking of concrete. Recommends for reinforced concrete construction near the sea in tropical countries, use of a rich concrete mix with aggregate so graded as to attain maximum density (that is, minimum permeability), extra thick cover (at least 1¼ in.) for the reinforcement and protection of upper surfaces from the intense drying action of tropical sun. This form of protection is under investigation.

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Causes of decay in concrete and methods of preserving against attack.

(36) "Action of Pure Water on Cement Mortar Briquets," *Engineering News-Record*, Vol. 100, February 9, 1928, p. 236.

French tests show disintegrating effect of distilled water; no change results from using river water.

(37) "Factors Affecting the Durability of Concrete," by F. R. McMillan, *Proceedings*, Portland Cement Assn., May, 1928, p. 73; *Engineering Journal*, March, 1928.

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Results of tests carried out by Dr. Otto Graf from 1920 to 1926 at Stuttgart.

(40) "Stability of Cements in Corrosive Waters," by G. Haegermann, *Pit and Quarry*, Vol. 15, p. 67 (1928).

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(42) "Action of Pure Water on Quick Setting Cements," by Mourral, *Le Genie Civil*, Vol. 92, p. 121 (1928).

Pure water does not readily break down quick-setting cements used in water mains.

(43) "Action of Pure Water on Various Hydraulic Cements," by P. Domolard, *Revue des Materiaux de Construction et Travaux Publics*, No. 224, p. 165 (1928).

Immunity of various concrete conduits to action of pure water due to an entirely physical characteristic of certain cements which enables the production of practically impermeable mortars.

(44) "Some Accelerated Freezing and Thawing Tests on Concrete," by C. H. Scholer, *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part II, p. 472 (1928).

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(45) "Small Causes, Great Effects," by B. Winkler, ***Tonindustrie Zeitung***, Vol. 53, No. 41, p. 731 (1929).

Brief description of two failures of rapid hardening portland-cement concrete. One traced to contamination of sand with clay. Other found brand of cement was changed but no alteration in water-cement ratio. Subsequent examination showed second brand should have been used with a lower water-cement ratio.

(46) "The Attainment of Durability in Concrete Structures," by J. F. Hough, *Engineering Journal* (Canada), Vol. 12, December, 1929, p. 617.

(47) "Action of Chemically Active Solutions on Cement and Mortar," by E. Probst and K. E. Dorsch, *Zement*, Vol. 18, No. 10 and 11 (1929).

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Report of Committee 803. Corrosion of concrete due to weathering, sea water, alkali soils and waters—causes, effects and control in (1) manufacture, (2) curing, (3) insulation or protection.

(49) "Action of Water Sweated Out of Concrete on Metals," by F. Hundeshagen, *Pit and Quarry*, Vol. 18, September 11, 1929, p. 41.

(50) "Performance—Ultimate Test for Concrete Quality," by F. R. McMillan, *Proceedings*, Portland Cement Assn., May, 1929, p. 79.

(51) "Deterioration of Concrete in Hydraulic Structures," by A. Ekwall, *Concrete*, Vol. 35, October, 1929, p. 21; *Technical Bulletin 16*, Royal Board for Water Developments, Sweden, July 1, 1929.

(52) "Destructive Effect of Liquids on Concrete and Its Prevention," by R. Grün, *Korrosion und Mettalschutz*, Vol. 5, April, 1929, p. 73.

(53) "Special Treatments Increase Resistance of Portland Cement Concrete," by S. R. Mitchell, *Chemical and Metallurgical Engineering*, Vol. 36, September, 1929, p. 564.

(54) "Fundamental Factor in Weathering of Rocks and a Comparison of Chemical Weathering of Stone in Buildings and in Nature," by E. Kaiser, *Chemie der Erde*, Vol. 4, p. 290 (1929).

(55) "Disintegration of Concrete in Canal Locks of Markian Waterways," by Ehrenberg, *Bautechnik*, Vol. 7, August 2, 1929, p. 505.

(56) "Disintegration of Concrete and Its Prevention," by K. Ostendorf, *Bautechnik*, Vol. 7, June 28, 1929, p. 435.

(57) "Stereoscopic Microscope as Aid in Detection of Concrete Destruction," by R. Grün, *Tonindustrie Zeitung*, Vol. 53, pp. 1039, 1048 (1929).

(58) "Decay of Stone in Buildings and Monuments," by R. M. Buchanan, *Quarry*, Vol. 34, No. 383, p. 8 (1929).

In all cases the determining influence of moisture is evident and decay generally progresses upward and downward in relation to soakage resulting from capillarity and gravity, respectively.

(59) "The Mechanism of Corrosion of Portland Cement Concrete with Special Reference to the Role of Crystal Pressure," by F. O. Anderegg, *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 332 (1929).

Action of sulfate, crystal pressure from efflorescent action. Effect of temperature drop; accelerated method of determining resistance to crystal pressure.

(60) "Will a Fifth Ingredient Assure Durability?" by A. H. White, *Concrete*, Vol. 34, March, 1929, p. 15.

(61) "Basic Principles of Concrete Making," by F. R. McMillan, *Engineering News-Record*, Vol. 102, April 11, p. 580; April 18, p. 625; April 25, p. 673; May 2, p. 705; May 9, 1929, p. 748; McGraw-Hill Book Co., Inc., New York, November, 1929.

(62) "Resistance to Deterioration," by M. Noyer, *Le Ciment*, Vol. 34, January, 1929, p. 19; *Revue des Matériaux de Construction et Travaux Publics*, No. 232, January, 1929, p. 21.

Resistance of reinforced concrete and concrete masonry to deterioration caused by physical, chemical, and climatic action and laboratory investigations on density, porosity, flexure, permeability, and resistance to gases as a means of combating deterioration.

(63) "Leaching Action of Water on Concrete," by G. Kathrein, *Zement*, Vol 19, 1930.

Strength of cement is greatly affected by leaching action of storage waters. On immersing in lime waters following four weeks in conductivity water there were great changes in length, mainly shrinkage. Author concludes that the dissolved ingredients greatly affect the results of tests of strength.

(64) "Lessons from Concrete Structures in Service," by R. B. Young, *Proceedings*, Am. Concrete Inst., Vol. XXV, p. 64 (1929).

(65) "Influence of Coarse Aggregates on the Durability of Concrete," by F. R. McMillan and C. W. Ward, *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part II, p. 816 (1929).

(66) "The Effect of Temperature on the Strength of Concrete," by C. C. Wiley, *Engineering News-Record*, Vol. 102, January 31, 1929, p. 79.

REPORT OF COMMITTEE C-10

ON

HOLLOW MASONRY BUILDING UNITS

Committee C-10 has held three meetings since making the last report to the Society in June, 1928. It is expected that a fourth meeting will be held prior to the presentation of this report to the Society, at the annual meeting in June.

During the past two years the committee has discussed several suggested revisions of the standards under its jurisdiction. The majority of the members who were unable to attend meetings have contributed discussions by letter, and the committee has had the benefit of the views of several individuals who are familiar with the use of the standards under the jurisdiction of the committee.

Some of the trade organizations have been lending their support to a change in the designation of units now commonly known as "hollow tile." A proposal to substitute the words "structural clay tile" for "hollow burned-clay tile" in the Standard Definition of Terms Relating to Hollow Tile (C 43 - 24) and to make similar substitutions in the other standards affected was urged before the committee in March, 1929. Since then, on two occasions, this proposed revision was submitted to letter ballot vote, but failed to receive the required number of affirmative votes for committee action. Although the majority of the members favored the revision, some desired that the industry present a more united front on the question before changing the nomenclature now used.

Among other live topics of discussion are included those pertaining to methods of capping for compressive strength tests, methods of testing T-shaped and L-shaped tiles, increase in the standard weight of 8 by 7¾ by 12-in. load-bearing tile and changes in the table of fire-resistance periods for load-bearing tile.

The Subcommittee on Concrete Masonry Units, organized during the past year, has prepared a proposed specification for concrete units. Copies have been distributed to all of the committee members in order that the proposed specifications may be considered at a meeting of the committee in June, 1930.

The committee has been reorganized in a way which would make each subcommittee responsible to the main committee for standards relating to specific materials. The following subcommittees have been organized:

Subcommittee I on Hollow Tile
Subcommittee II on Concrete Masonry Units
Subcommittee III on Dimensions of Hollow Masonry Building Units
Subcommittee IV Editorial
Subcommittee V on Definitions

It is planned that sections within each of these subcommittees will be appointed for the purpose of investigating special phases of the general assignment of the subcommittee.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards are given in detail. Those mentioned in previous reports are presented without comment, but brief statements of the purpose of the proposed revision follow each of the recommendations being submitted for the first time.

Advancement to Standard of Revisions of Standards.—The committee recommends that the following revisions of standards be submitted to letter ballot of the Society for adoption. These revisions are divided into two groups, as follows:

Group A.—Revisions published as tentative since 1928[1] which the committee now recommends be adopted as standard:

Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27);[2] and

Standard Specifications and Tests for Hollow Burned-Clay Floor Tile (C 57 – 27).[3]

Group B.—Revisions proposed for the first time which the committee recommends be referred to letter ballot of the Society by the necessary nine-tenths vote of the annual meeting for immediate adoption as standard:

Standard Specifications and Tests for Hollow Burned-Clay Load-Bearing Wall Tile (C 34 – 27):[2]

Section 3.—Under the table of requirements in Paragraph (*a*) add the following note. The purpose of the note is to provide weight requirements for tiles of similar design but of smaller sizes than those listed. Data supplied to the committee by manufacturers indicated that a sufficient quantity of tiles of the smaller sizes were produced to warrant some provision for them in the specifications.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vols. 28 and 29, Part I, pp. 1123 and 862, respectively (1928 and 1929); also 1929 Book of A.S.T.M. Tentative Standards, pp. 816 and 817.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 213.

[3] *Ibid.*, p. 219.

NOTE.—Units of the same general design as those listed in the above table, but of smaller size, shall weigh not less per unit volume.

Change Paragraph (*b*) to read as follows by the addition of the italicized words. A change in the weight requirements permitting the use of heavier tiles has been under consideration for about three years. The chief purpose of the change is to permit the unrestricted use of the standards where local requirements specify the shell thickness of tiles:

(*b*) A tolerance of 5 per cent *under and 12.5 per cent over* will be allowed on the above standard weights.

Advancement of Tentative Standard to Standard.—The Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 – 28 T)[1] were first issued by the Society in 1924, having since been slightly revised in 1926, 1927 and 1928. During the past two years, there have been criticisms of these specifications from several sources relative to the strength requirements, because of the fact that units meeting the requirements would be required to have strengths in some cases as great as for load-bearing tile. It was pointed out that for fireproofing, partition and furring tile, strength was not an important consideration and that only sufficient strength to withstand safely the rough usage in shipment was required.

The proposal to eliminate all requirements relating to strength was placed before the committee in 1929. The committee now recommends that the specifications be revised by the elimination of the strength requirements and the methods of test pertaining thereto, and the specifications as revised be advanced to standard. The specifications in their revised form are appended hereto.[2] This radical change in the specifications has the support of the majority of the members as is indicated in the analysis of the letter ballot on this item.

The above recommendations have been submitted to letter ballot of the committee with the following results:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 859 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 251.

[2] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 278.—ED.

Items	Affirm-ative	Neg-ative	Not Voting
I. ADVANCEMENT TO STANDARD OF TENTATIVE REVISIONS OF STANDARDS			
Standard Specifications and Tests for Hollow Burned-Clay Load-Burning Wall Tile (C 34 - 27)	21	1	2
Standard Specifications and Tests for Hollow Burned-Clay Floor Tile (C 57 - 27)	21	1	2
II. PROPOSED REVISION OF STANDARD			
Standard Specifications and Tests for Hollow Burned-Clay Load-Burning Wall Tile (C 34 - 27), immediate adoption	21	1	2
III. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile (C 56 - 28 T), as revised	20	1	3

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 31 members; 24 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

D. E. PARSONS,
Chairman.

H. D. FOSTER,
Secretary.

EDITORIAL NOTE

The tentative revisions of the Standard Specifications and Test for Hollow Burned-Clay Load-Bearing Wall Tile and for Hollow Burned-Clay Floor Tile were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 272 and 282, respectively.

The proposed immediate revision of the Standard Specifications and Tests and Hollow Burned-Clay Load-Bearing Wall Tile was approved at the annual meeting by a unanimous vote and was subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 272.

The Tentative Specifications and Tests for Hollow Burned-Clay Fireproofing, Partition and Furring Tile, as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, page 278.

REPORT OF COMMITTEE C-11

ON

GYPSUM

Committee C-11 on Gypsum held two meetings during the past year, both at the U. S. Bureau of Standards, Washington, D. C., one on October 25, 1929, and the other on March 14, 1930. A third meeting will be held at Atlantic City, N. J., in conjunction with the annual meeting of the Society.

The committee has experienced a deep loss in the death of Mr. F. A. Wilder, one of its members since the committee was organized in 1914. During the intervening years his attendance was as regular as his health would permit, and his knowledge, patience, and kindly spirit contributed much to the success of the committee.

The addition of the following members to the committee has not disturbed the balance of producer and non-producer membership: Mr. L. S. Wells, of the U. S. Bureau of Standards, general interest; Mr. E. T. Longstreth, of Philadelphia, Pa., Samuel H. French & Co., producer; and the National Gypsum Co., Buffalo, N. Y., represented by D. D. Crandall, producer.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Gypsum for Various Uses (Oliver Bowles, acting chairman).—In the study of the action of different forms of calcium sulfate as a retarder for portland cement, Mr. P. S. Roller of the U. S. Bureau of Mines, New Brunswick Station, who is cooperating with the subcommittee, is undertaking a fundamental study of the problem. One of the first steps being undertaken is to determine the solubility and rate of solubility of the different forms of calcium sulfate and of the particle size. The fractionating of material ground and sieved through a 74-micron (No. 200) sieve into a number of particle-size groups is done by means of a new air analyzer developed by Mr. P. S. Roller. This appratus is capable of rendering accurate separations down to a few microns.

Subcommittee II on Gypsum Plasters (J. M. Porter, chairman).—This subcommittee has continued its review of the Tentative Specifications for Keene's Cement (C 61 – 29 T) and for Calcined Gypsum for Use in the Preparation of Dental Plasters (C 72 – 29 T). Revisions in these specifications are being proposed as mentioned later in this report and the specifications as revised are recommended for adoption as standard.

Subcommittee III on Structural Gypsum Products (H. W. Reel, chairman).—An investigation of the properties of gypsum fiber concrete has been in progress for about two years. The result of this investigation are given in the Appendix to this report.

This subcommittee has prepared Proposed Tentative Specifications for Gypsum Sheathing Board, appended hereto,[1] which are being recommended for publication as a tentative standard.

Subcommittee IV on Testing Methods (H. E. Brookby, chairman).—A section of the subcommittee was appointed to review the Standard Methods of Testing Gypsum and Gypsum Products (C 26 – 27) with a view to expediting testing procedure. The results of this committee's activities is reflected in the number of revisions being recommended as mentioned later in the report. Tests to substantiate the changes suggested were conducted by various members as well as by the U. S. Bureau of Standards.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The following recommendations are made to the Society relative to the standards and tentative standards under the jurisdiction of Committee C-11:

Proposed New Tentative Standard.—Gypsum sheathing board as a sheathing material on wood frame construction has been in common use for the past six years. Based on the experience gained during this period and tests conducted by one of the members of the committee, Committee C-11 recommends the Proposed Tentative Specifications for Gypsum Sheathing Board, appended hereto,[1] for publication as tentative.

Proposed Revisions of Standards.—A review of the standard specifications for gypsum and gypsum plasters under the jurisdiction of Committee C-11 revealed a number of inconsistencies in the sections on sampling and on packing and marking. As a result of this review, the revisions given in detail below are being recommended for immediate adoption in four standard specifications. For other reasons mentioned below, revisions are also recommended in the Standard Specifications for Gypsum Plastering Sand (C 35 – 25), Specifications for Gypsum Plaster Board (C 37 – 25) and in the Standard Methods of Testing Gypsum and Gypsum Products (C 26 – 27).

Standard Specifications for Calcined Gypsum (C 23 – 22).[2]—It has developed that Paragraph (*b*) of Sections 5, 6 and 7 of these specifications contain requirements for gypsum pottery and gypsum molding plaster. Since requirements for these plasters are given in separate standard specifications of the Society it is recommended that these requirements should be withdrawn from the Standard Specifications C 23 – 22. Also calcined gypsum is shipped both in packages and in bulk although the section on sampling covers only the sampling of packages. The committee feels that a section on sampling of bulk shipments should be added to these specifications. These changes as well as changes in form have been made in the specifications appended hereto[1] and the committee accordingly recommends that these specifications be adopted to replace the present Standard Specifications C 23 – 22. This recommendation will require a nine-tenths vote for immediate adoption.

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[1] See p. 1019.—ED.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 75.

Standard Specifications for Gypsum Plasters (C 28 – 27).[2]—It is recommended that these specifications be rearranged to agree with the Regulations Governing the Form but not the Substance of Standards. The specifications will be rearranged in the same order as shown in the proposed revision of the Standard Specifications for Calcined Gypsum (C 23 – 22), appended hereto.[1] It is also recommended that since gypsum plasters are shipped only in packages the section on packing and marking be revised as follows, and the specifications as revised continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Section 20.—Change from its present form: namely,

20. (*a*) Gypsum plasters shall be dry and free from lumps, and may be shipped either in packages or in bulk.

(*b*) When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of Manufacturer.
Brand.
Description.
Net weight of package.

(*c*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

to read as follows:

20. (*a*) Gypsum plasters shall be dry and free from lumps, and shall be shipped in packages.

(*b*) When shipped for resale, the following information shall be legibly marked on each package or on a tag of suitable size attached thereto:

Name of Manufacturer.
Brand.
Description.
Net weight of package.

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[1] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 97.—ED.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 78.

Standard Specifications for Gypsum Molding Plaster (*C 59 – 29*)[1] *and Standard Specifications for Gypsum Pottery Plaster* (*C 60 – 29*).[2]—It is recommended that these specifications be revised as follows and continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Section 9 (*a*).—Change from its present form: namely,

9. (*a*) Gypsum molding (or pottery) plasters shall be dry and free from lumps and may be shipped in 100-lb. cloth sacks, 100-lb. paper-lined cloth sacks, 100-lb. paper sacks, 80-lb. paper sacks or 250-lb. (235 lb. net) barrels.

to read as follows:

9. (*a*) Gypsum molding (or pottery) plaster shall be dry and free from lumps and shall be shipped in packages.

Standard Specifications for Gypsum Plastering Sand (*C 35 – 25*).[3]—A plastering sand specification has been developed by the National Sand and Gravel Association through a joint committee of representatives of national organizations interested in the protection and use of plastering materials. The committee has been interested in this work and recommends the following revision of Section 2 of the present standard specifications:

Section 2.—Change from its present form: namely,

2. It shall be graded from fine to coarse, and when dry not more than 6 per cent weight shall be retained on a No. 8 (2380-micron) sieve; not less than 80 per cent by weight shall be retained on a No. 50 (297-micron) sieve; and not more than 6 per cent by weight shall pass a No. 100 (149-micron) sieve. These sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (Serial Designation: E 11) of the American Society for Testing Materials.

to read as follows:

2. Gypsum plastering sand shall be graded from fine to coarse within the following limits:

	PERCENTAGE RETAINED	
	MAXIMUM	MINIMUM
Retained on a No. 4 (4760-micron) sieve	0	..
Retained on a No. 8 (2380-micron) sieve	10	0
Retained on a No. 30 (590-micron) sieve	80	15
Retained on a No. 50 (297-micron) sieve	95	70
Retained on a No. 100 (149-micron) sieve	..	95
Weight removed by decantation	not more than 5 per cent	

The sieves shall conform to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials.

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[1] 1929 Supplement to Book of A.S.T.M. Standards, p. 129.

[2] *Ibid.*, p. 131.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 82.

Standard Methods of Testing Gypsum and Gypsum Products (C 26 - 27).[1]—The committee recommends that these methods be revised as follows and continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption:

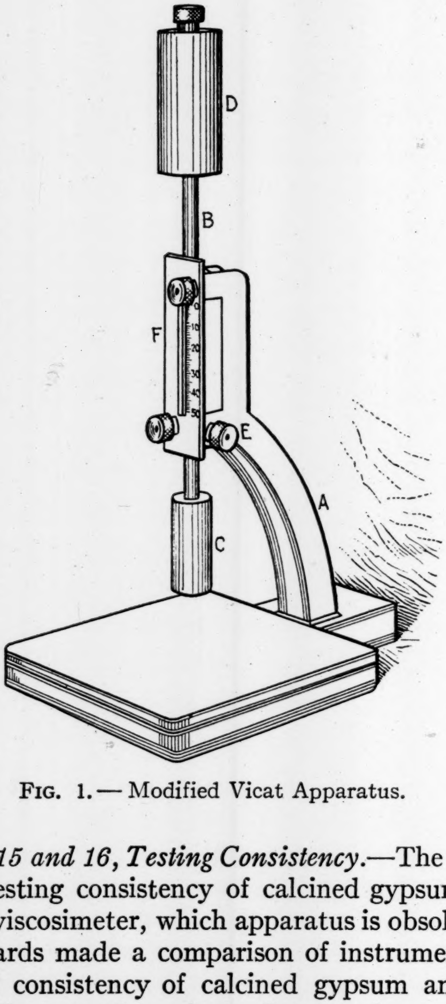

FIG. 1.— Modified Vicat Apparatus.

Sections 14, 15 and 16, Testing Consistency.—The present method of determining testing consistency of calcined gypsum is by means of the Southard viscosimeter, which apparatus is obsolete. The U. S. Bureau of Standards made a comparison of instruments for measuring the standard consistency of calcined gypsum and submitted a report of its findings to Committee C-11 at the spring meeting in 1929. Based on this report and subsequent experiments with the modified Vicat apparatus, Committee C-11 recommends that Sections 14, 15 and 16 be changed from their present form to read as follows:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 94.

14. In order that the results of testing samples of different plasters shall be directly comparable, it is necessary that all calcined gypsum be first brought to the same consistency, by the addition of the proper amount of water. An accurate method for determining this consistency is the most important step in the standardizing of physical methods for testing cementing materials.

15. *Apparatus.* (*a*) *Modified Vicat Apparatus.*—The modified Vicat apparatus (Fig. 1) consists of a frame, *A*, bearing a movable brass rod, *B*, 0.25 in. in diameter and 6 in. in length on the lower end of which is attached a plunger, *C*, 0.75 in. in diameter and 1.75 in. in length made of aluminum tubing. The total weight of the rod with plunger is 50 g. This total weight may be increased by means of weight, *D*, screwed into the rod. The rod can be held in any position by means of a screw, *E*, and has a mark midway between the ends which moves under a scale, *F*, graduated in millimeters, attached to the frame, *A*.

(*b*) *Mold.*—The conical ring mold shall be made of a non-corroding, non-absorbent material, and shall have an inside diameter of 7 cm. at the base, 6 cm. at the top and a height of 4 cm.

(*c*) *Base Plate.*—The base plate for supporting the ring mold shall be of plate glass and about 10 cm. square.

16. *Method* (*a*) *Preparation of Apparatus.*—Clean the plunger, mold and base plate of the modified Vicat apparatus. Apply a thin coat of vaseline or other suitable lubricant to the upper surface of the base plate in order to prevent leaks during the test.

(*b*) *Procedure.*—To a known volume of water, add approximately 0.2 g. of commercial retarder, weigh out 200 g. of the sample and sift it into the water by sieving through a No. 8 (2380-micron) sieve, allowing it to soak for 2 minutes. Then stir to an even fluidity. Pour this mixture into the ring mold, work slightly to remove air bubbles and strike off flush with the top of the mold. Wet the plunger and then lower it to the surface of the mix, approximately at the center of the mold. Read the scale and release the plunger immediately. After the rod has settled read the scale again.

Readings are reproducible on a retarded mix and therefore in order to eliminate errors two or three determinations should be made on each mix, care being taken to have the mold completely filled and the plunger clean and wet.

17. *Testing Consistency.*—A neat mortar mixture shall be considered of testing consistency when a penetration of 30 mm. ± 2 mm. is obtained when tested in accordance with Section 16 and the testing consistency shall be expressed as the number of cubic centimeters of water required to be added to 100 g. of the gypsum.

Section 21.—Change the fifth sentence from its present form: namely,

When sufficiently hard, remove and store in the room at a temperature of not less than 15.6° C. (60° F.) nor more than 37.8° C. (100° F.) for at least seven days.

to read as follows:

Retain briquets in molds in moist air (not less than 24 hours) until thoroughly hardened. Remove from molds and store specimens in the room at a temperature of not less than 21.1° C. (70° F.) nor more than 37.8° C. (100° F.) to complete a minimum 7-day aging period.

Section 22.—The standard specimen used to determine compressive strength of neat calcined gypsum and sanded mixtures is the cylinder. Committee C-11 feels, in view of the difficulty the average testing laboratory has in making cylinders from gypsum, that the cube specimen on account of its facility in molding, will give much more accurate and uniform results. A cube also provides two parallel faces for making tests.

The U. S. Bureau of Standards and the United States Gypsum Co. ran a series of comparative tests of 2 by 4-in. cylinders and 2-in. cubes which show that cubes can be substituted for cylinders without any sacrifice. There are considerable laboratory data which substantiates these test reports.

The committee therefore recommends that Section 22 be changed from its present form to read as follows:

> 22. Mix 1500 g. of the sample to testing consistency. Cast into five 2-in. split cubes set plumb upon metal or glass plates. Do not cast each cube successively, but move the containing vessel back and forth over the cubes while pouring continuously. Work the cubes slightly with the point of the trowel to remove air bubbles, and level off the top of the cubes. Retain cubes in molds in moist air (not less than 24 hours) until thoroughly hardened. Remove from molds and store specimens in the room at a temperature of not less than 21.1° C. (70° F.) nor more than 37.8° C. (100° F.) to complete a minimum 7-day aging period. Weigh once a day and when the weight has become constant to within 0.1 per cent, proceed to test the specimens in a standard testing machine used for the determination of compressive strength.
>
> NOTE.—When the material to be tested is a sanded mixture, use not less than 2000 g. of the sample and mix to testing consistency for sanded mixture.
>
> The average compressive strength of the cubes tested shall be reported as the compressive strength of the material, except that if the results on one or two of the cube specimens vary more than 15 per cent from the average, the compressive strength shall be reported as the average of the remaining specimens. The compressive strength of all the cubes shall be reported.

Section 26.—The standard size of gypsum plaster board is now 16 in. in width and 32 or 48 in. in length. The standard specimen for determining strength is 12 by 18 in. in size. It is, therefore, impossible to obtain a standard size specimen for test with the load applied parallel to the grain in the paper surfacing. However, this is not so important since the new type of board is erected running across the supporting studs rather than with the studs. At the October, 1929, meeting the committee reviewed considerable data on tests of gypsum boards with supports 14 in. on centers as compared to the present standard span of 16 in. and the committee felt at that time that the entire section on testing boards should be revised. On reconsideration at the March meeting, it was felt wise not to attempt such a radical change at this time. It is believed, however, that for the present this condition can be satisfactorily met by the addition to Section 26 of an explanatory note. The committee therefore recommends that the following note be added to this section:

NOTE.—In testing gypsum boards of such narrow width that the longest dimension of the standard test specimen cannot be cut across the fiber of the surfacing, the strength test with knife edges parallel to the fiber of the surfacing may be omitted.

Standard Specifications for Gypsum Plaster Board (C 37 – 25).[1]—The committee recommends that the same note which it is proposed be added to Section 26 of the Standard Method C 26 – 27 as given above be inserted after Section 13 of the Standard Specifications C 37 – 25 and that the specifications as revised be continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Advancement of Tentative Standard to Standard.—The committee presents the following revisions in two of its tentative specifications and recommends that the specifications as revised be advanced to standard.

Tentative Specifications for Keene's Cement (C 61 – 29 T).[2]—With the object of adopting the modified Vicat apparatus described above under the proposed revision of the Standard Methods of Testing Gypsum and Gypsum Products (C 26 – 27) for determining standard consistency of Keene's cement, the research laboratories of Best Brothers Keene's Cement Co., and the United States Gypsum Co. have been conducting a series of tests on Keene's cement. As the result of these investigations it is recommended that these tentative specifications be revised as follows and advanced to standard:

Section 8.—Change this section from its present form to read as follows:

8. The chemical and physical properties of Keene's cement shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (A.S.T.M. Designation: C 26) of the American Society for Testing Materials, except that in the determination of the time of setting and tensile strength, the consistency used shall be such that a 350-g. modified Vicat needle, described in Section 15 of the Standard Methods C 26 shall give a penetration of 20 mm. ± 2 mm., 20 seconds after release, the measurement being made 20 minutes after the addition of the Keene's cement to the gaging water.

NOTE.—A 20-minute mixing-and-soaking period for the Keene's cement and water, with occasional stirring to remove entrained air or gas bubbles, is required as follows:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 86.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 622 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 201.

(*1*) Before the determination of testing consistency.

(*2*) Before the determination of time of setting (the soaking time to be included in the time of setting).

(*3*) Before filling the molds in the strength determinations.

The use of 0.1-per-cent retarder in determining testing consistency is optional.

Section 9.—Change this section from its present form: namely,

9. The cement may be shipped in either packages or in bulk.

to read as follows:

9. Keene's cement shall be dry and free from lumps and shall be shipped in packages.

Delete Paragraph (*b*), which reads as follows:

(*b*) When shipped in bulk, a card containing the required information shall be conspicuously placed in the carrier.

Tentative Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters (*C 72 - 29 T*).[1]—In accordance with the recommendations of manufacturers of dental plasters it was deemed advisable to extend the setting time of calcined gypsum of Grade S from 30 to 40 minutes and to require the stirring of dental plasters before being placed in the molds for determining time of set and tensile strength. It is accordingly recommended that these tentative specifications be revised as follows and advanced to standard:

Section 3 (*c*).—Change to read as follows by the addition of the italicized figure and the omission of the figure in brackets:

(c) Grade S.—Shall set in not less than 20 not more than [30] *40* minutes.

Section 6.—It is recommended that this section, which reads as follows, be incorporated in Section 10 under the heading "Packing and Marking." This will require the renumbering of the remaining sections accordingly:

6. The calcined gypsum shall be dry and free from lumps.

Section 9.—Change this section from its present form to read as follows:

9. The chemical and physical properties of calcined gypsum for use in the preparation of dental plasters shall be determined in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (A.S.T.M. Designation: C 26) of the American Society for Testing Materials, except that in the determination of the time of setting and the tensile strength, the calcined gypsum and water shall be mixed in the proportion of 100 g. of calcined gypsum to 60 cc. of water. The calcined gypsum shall be allowed to soak in distilled water at 70° F. for 30 seconds, and shall then be stirred for 30 seconds and placed immediately in the molds.

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[1] ***Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 625 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 204.**

Section 10.—Add as Paragraph (*a*) the following sentence, renumbering the present section as Paragraph (*b*):

10. (*a*) Calcined gypsum for use in the preparation of dental plasters shall be dry and free from lumps and shall be shipped in packages.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. NEW TENTATIVE STANDARD			
Tentative Specifications for Gypsum Sheathing Board	20	0	5
II. PROPOSED REVISIONS OF STANDARDS			
Standard Specifications for Calcined Gypsum (C 23 - 22), immediate adoption	23	0	2
Standard Specifications for Gypsum Plasters (C 28 - 27), immediate adoption	22	0	3
Standard Specifications for Gypsum Plaster Board (C 37 - 25), immediate adoption	22	0	3
Standard Specifications for Gypsum Molding Plaster (C 59 - 29), immediate adoption	21	0	4
Standard Specifications for Gypsum Pottery Plaster (C 60 - 29), immediate adoption	21	0	4
Standard Methods of Testing Gypsum and Gypsum Products (C 26 - 27), immediate adoption	21	0	4
III. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Specifications for Keene's Cement (C 61 - 29 T), as revised	20	0	5
Tentative Specifications for Calcined Gypsum for Use in the Preparation of Dental Plasters (C 72 - 29 T), as revised	19	0	6

This report has been submitted to letter ballot of the committee, which consists of 32 members; 25 members returned their ballots, of whom 24 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

J. W. GINDER,
Chairman.

H. J. SCHWEIM,
Secretary.

EDITORIAL NOTE

The proposed Tentative Specifications for Gypsum Sheathing Board were accepted for publication as tentative and appear on page 1019.

The proposed immediate revisions of the Standard Specifications for Calcined Gypsum, for Gypsum Plasters, for Gypsum Plaster Board, for Gypsum Molding Plaster, and for Gypsum Pottery Plaster, were unanimously approved at the annual meeting and subsequently adopted by letter ballot vote of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 97, 105, 117, 109 and 111, respectively.

The revision proposed for immediate adoption in the Standard Specifications for Gypsum Plastering Sand, inadvertently omitted from the preprinted report and proposed on the floor of the annual meeting, was accepted, (see Summary of Proceedings, page 42), and approved at the annual meeting by a unanimous vote and was subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 113.

The revisions proposed for immediate adoption in the Standard Methods of Testing Gypsum and Gypsum Products as revised on the floor of the annual meeting, (see Summary of Proceedings, page 41), was approved at the annual meeting by a unanimous vote, and was subsequently adopted by letter ballot of the Society on September 2, 1930. The standard methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 125.

The Tentative Specifications for Keene's Cement and for Calcined Gypsum for Use in the Preparation of Dental Plasters were approved at the annual meeting and subsequently adopted by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 102 and 100, respectively.

APPENDIX

PROPERTIES OF GYPSUM FIBER CONCRETE

INTRODUCTION

Committee C-11 on Gypsum has defined gypsum concrete as follows:

> *Gypsum Concrete.*—A combination of aggregate or aggregates with gypsum as a binding medium, which after mixing solidifies into a conglomerate mass.

When an aggregate consisting of wood shavings is used, the resulting product is designated "gypsum fiber concrete."

Gypsum fiber concrete is used for precast and poured-in-place floors and roofs in much the same manner as portland-cement concrete. It has certain advantages, such as lightness and quick set. The use of the material has increased at such a rate in the past few years that it has become desirable to include requirements for it in building codes. Few data have been developed relating to gypsum fiber concrete, and most of the data have not been in an available form.[1, 2, 3]

Because of the lack of design information and data on which building code requirements might be based, Committee C-11 appointed a sub-committee to outline the program necessary to obtain the desired data. The subcommittee consisted of J. M. Porter, Chemical Engineer, Structural Gypsum Corp., Linden, N. J., chairman; A. H. Beyer, Professor of Civil Engineering, Columbia University, New York; H. E. Brookby, Consulting Engineer, Chicago; A. W. Kraemer, Chief Engineer, H. E. Marks Corp., Pittsburgh, Pa.; and G. E. Strehan, Consulting Engineer, New York.

G. H. Way was appointed research associate at the Bureau of Standards by the Gypsum Industries to conduct this work. J. A. Murray, Chief, Lime and Gypsum Products Section, Bureau of Standards, supervised the investigation and together with Way prepared the report. Acknowledgment is hereby made of the valuable aid rendered by these men.

This report, containing the results of the investigation outlined by the subcommittee, has been submitted to and approved by the members of the subcommittee.

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[1] Tests by Beaver Products Co., United States Gypsum Co., H. E. Marks Corp., and Structural Gypsum Corp. were reported upon before Committee C-11 in 1926, the reports appearing in the minutes of the committee.

[2] W. A. Slater and G. P. Anthes, "Tests of Plain and Reinforced Gypsum Specimens," *Journal*, Western Society of Engineers, Vol. XXIV, No. 7, September, 1919.

[3] Gypsum Composition Slab Construction for Roofs and Floors," *Bulletin 25*, Public Works of the Navy, p. 20 (1917).

GENERAL

In the design of floors and roofs, gypsum fiber concrete is used in the same manner as portland-cement concrete, being reinforced with steel to resist tensile stresses. The gypsum concrete must provide sufficient compressive, shearing, and bond strengths to act in combination with the steel reinforcing. The determination of the compressive strength of gypsum fiber concrete formed the main part of this investigation.

Two gypsum fiber concretes, based upon the fiber content, are in general use. One concrete contains 3 per cent by weight or less of the fibrous aggregate while the other contains approximately $12\frac{1}{2}$ per cent of aggregate. The investigation covered each of these types. In addition, some tests were made on neat gypsum mixes as a basis of control to determine the characteristics of the neat gypsum used in the tests and some mixes containing 10 per cent of fiber were tested to determine the properties of a fibered mix between the two extremes which are in general use.

The nomenclature used in this report in expressing the composition of the gypsum fiber concrete consists of three figures representing, respectively, the parts by weight of calcined gypsum, wood chips and water. For example 97:3:60 represents a mixture of 97 parts of calcined gypsum, 3 parts of wood chips and 60 parts of water. The first two figures always total 100, so that the second figure represents the percentage of aggregate in the dry mix before gaging with water, while the third figure represents the quantity of mixing water, expressed, according to the custom in the industry, as a percentage of the combined weights of the gypsum and wood chips.

Two series of tests are reported herein. An earlier series is not reported as it was a preliminary test, necessary in the development of the operating technique and the results are not as reliable as those of the other two, although they verify the conclusions. The specimens used in the first series of the present investigation consisted entirely of cast cylinders. Those used in the second series consisted principally of specimens cut from cast slabs with enough cast cylinders to develop the relation between the two types.

SERIES NO. 1: TESTS OF CAST CYLINDERS

Outline of Tests:

The first series of tests was made on cast 6 by 12-in. cylinders of gypsum fiber concrete. There were three specimens of each mix. After capping with plaster of Paris the cylinders were dried at 100° F.

to constant weight before testing. The specimens were tested approximately 28 days after casting. Two specimens of each mix were broken in compression while the third was used for determining the modulus of elasticity, after which it also was broken in compression. The weights per cubic foot of the gypsum concrete, both wet and dry, and of the loose dry mix before gaging with water were also determined.

Materials Used:

There are two methods of calcining gypsum; the kettle process and the rotary-kiln process. Samples of calcined gypsum from each process were used in this investigation and are designated as Gypsum I and Gypsum II, respectively. Gypsum I was chosen because of its high SO_3 content and high testing consistency, while Gypsum II was chosen to represent the lower limit of SO_3 content and consistency, so as to cover the widest range in characteristics met with in the field. The chemical and physical properties of each are given in Table I.

TABLE I.—PROPERTIES[a] OF CALCINED GYPSUMS USED FOR GYPSUM FIBER CONCRETE IN SERIES NO. 1.

	GYPSUM I FIRST SETTLE, KETTLE CALCINED.	GYPSUM II FIRST SETTLE, ROTARY CALCINED.
Standard testing consistency, per cent	68	50
Time of set, minutes	24	29
Tensile strength, lb. per sq. in.	320	320
Fineness:		
Retained on No. 30 sieve, per cent	0	0
Passing No. 30, retained on No. 100 sieve, per cent	14	19
Passing No. 100 sieve, per cent	86	81
Chemical analyses:		
Silica (SiO_2), per cent	0.4	2.1
Lime (CaO), per cent	38.8	36.6
Sulfur trioxide (SO_3), per cent	53.3	47.5
Combined water (loss at 220° C.), per cent	7.2	6.0
Calcined gypsum ($CaSo_4 \cdot \frac{1}{2}H_2O$),[b] per cent	96.5	86.0

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[a] Tests were made in accordance with the Standard Methods of Testing Gypsum and Gypsum Products (A.S.T.M. Designation: C 26), see 1927 Book of A.S.T.M. Standards, Part II, p. 94.

[b] Calculated from the SO_3 content.

The fiber or wood chips were kiln-dried soft pine planer shavings. Most of the shavings were less than 1 in. in greatest dimension and less than $\frac{1}{16}$ in. in thickness.

Weights:

The weight per cubic foot of the dry mix of calcined gypsum and wood chips was determined. The ingredients were weighed out separately, mixed thoroughly by hand, and the mixture was poured carefully into a tared cylindrical container, 6 by 6 in. inside dimensions. The top was struck off level with a straight edge, precautions being taken to prevent jarring and consequent compacting of the material, and the whole was then weighed. The results were calculated to pounds per cubic foot and are given in Table II. Each figure is the average of at least two determinations. The weight of the wood chips used was from 3 to 5 lb. per cu. ft.

Table II.—Weight in Pounds per Cubic Foot of Dry and Loose Gypsum-Chip Mixes.

Mix	Gypsum I Kettle Calcined	Gypsum II Rotary Calcined
100:0	59	60
97:3	56	56
90:10	38	43
87.5:12.5	31	34

Table III.—Weight in Pounds per Cubic Foot of Wet, Gypsum Fiber Concrete.

Mix	Gypsum I, Kettle Calcined			Gypsum II, Rotary Clacined		
	60 per cent Water	70 per cent Water	80 per cent Water	50 per cent Water	60 per cent Water	70 per cent Water
100:00	100	96	..	104	100	..
97:3	95	93	..	100	96	..
90:10	..	85	83	..	87	86
87.5:12.5	..	83	81	..	82	84

The weight of the wet gypsum fiber concrete was determined by weighing the specimens immediately after the molds were removed. The results were calculated to pounds per cubic foot and are given in Table III.

The weight of the dry gypsum fiber concrete was determined by weighing the specimens after drying to constant weight in air in the laboratory. The results calculated to pounds per cubic foot are given in Table IV.

Construction of Specimens:

The method used for the construction of the specimens in this series was as follows: The calcined gypsum and the wood chips were weighed our separately in the correct proportions and thoroughly mixed; a weighed amount of water was then added and the whole mixed thoroughly by hand for 2 minutes. An oiled 6 by 12-in. steel mold, resting on a machined steel plate, was then filled approximately one-third full with the mixture and rodded 30 times with a bullet-nosed steel rod $\frac{5}{8}$ in. in diameter and 24 in. in length. The mold was then filled to approximately two-thirds and again rodded, and finally filled, rodded, and the top struck off level with a straight edge. The material set hard in 30 minutes or less but the molds were not stripped until 2 hours had elapsed. After removal of the molds, the specimens were stored in the laboratory for 7 days, and then capped on the upper surface with plaster of Paris. It was not necessary to cap the surface which had rested on the machined steel plate. The capped specimens were stored in the laboratory for 3 to 4 weeks before being dried to constant weight in an oven at 100° F. The weight was considered constant when two consecutive weighings at 24-hour intervals agreed within 5 g. (approximately 0.1 per cent of the total weight).

TABLE IV.—WEIGHT IN POUNDS PER CUBIC FOOT OF GYPSUM FIBER CONCRETE DRIED TO CONSTANT WEIGHT AT ROOM TEMPERATURE.

Mix	Gypsum I, Kettle Calcined			Gypsum II, Rotary Calcined		
	60 per cent Water	70 per cent Water	80 per cent Water	50 per cent Water	60 per cent Water	70 per cent Water
100:0	74	68	..	79	76	..
97:3	69	64	..	77	70	..
90:10	..	56	52	..	62	57
87.5:12.5	..	56	52	..	60	55

TABLE V.—COMPRESSIVE STRENGTH IN POUNDS PER SQUARE INCH OF GYPSUM FIBER CONCRETE, OVEN-DRIED TO CONSTANT WEIGHT AT 110° F.

Mix	Gypsum I, Kettle Calcined			Gypsum II, Rotary Calcined		
	60 per cent Water	70 per cent Water	80 per cent Water	50 per cent Water	60 per cent Water	70 per cent Water
100:0	1990	1200	...	1650	1090	...
97:3	840	620	...	1340	770	...
90:10	...	580	450	...	590	410
87.5:12.5	...	500	430	...	470	400

Compressive Strength:

The compressive strength of all specimens was determined in the usual manner, using a 50,000-lb. testing machine fitted with spherical bearing head to obtain uniform loading. The results, calculated to pounds per square inch, are given in Table V. Each value is the average of three specimens.

Modulus of Elasticity:

As stated above, one specimen from each mix was used for determining the modulus of elasticity of the concrete. The vertical deformations in the specimens were measured over an 8-in. length by a clamp-type compressometer having a single micrometer dial reading to 0.0001 in. This instrument is illustrated in Fig. 1.

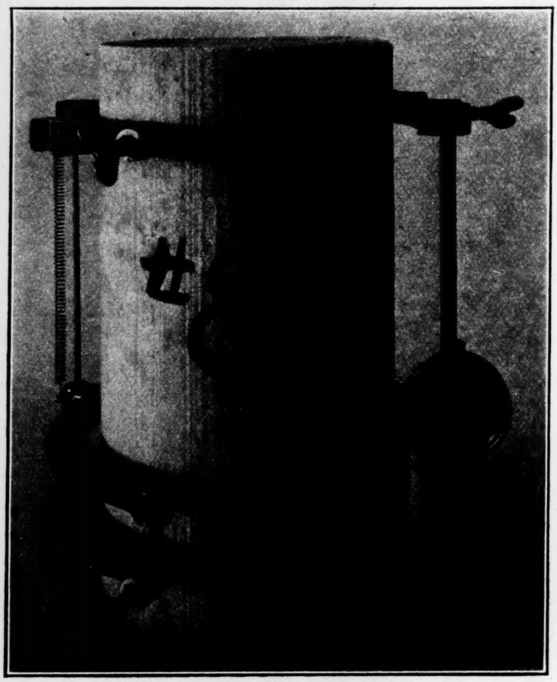

FIG. 1.—Compressometer for Measuring Vertical Deformations of Specimens.

The load on the specimen was applied in small increments, dial readings being recorded with each increment, until the load was approximately three-fourths of the ultimate determined from the specimens previously broken in straight compression. The compressometer was then removed and the load increased until failure occurred.

The stress-strain curves plotted from the data thus obtained are shown in Figs. 2 to 5. Table VI gives the initial tangent and secant moduli of elasticity for the gypsum fiber concrete dried to constant weight at 100° F. The secant moduli are taken at 30 per cent of the ultimate load.

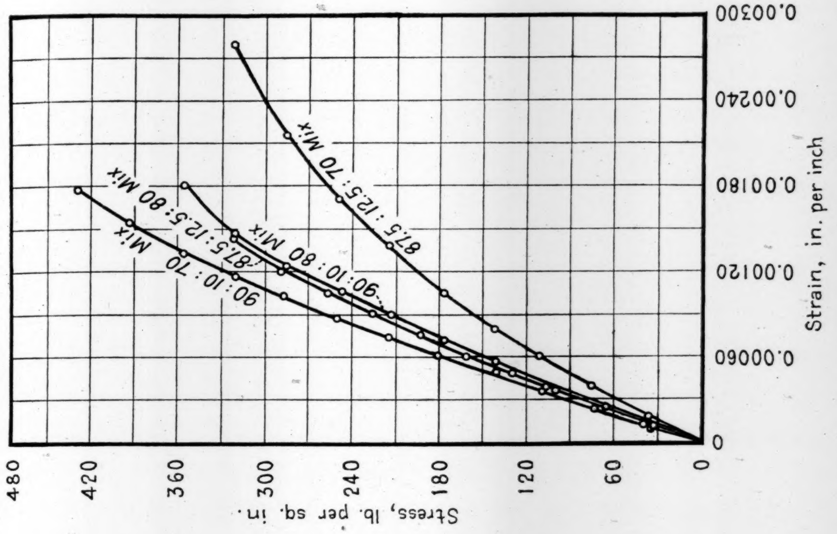

FIG. 3.—Stress-Strain Curves for Gypsum I Mixes.

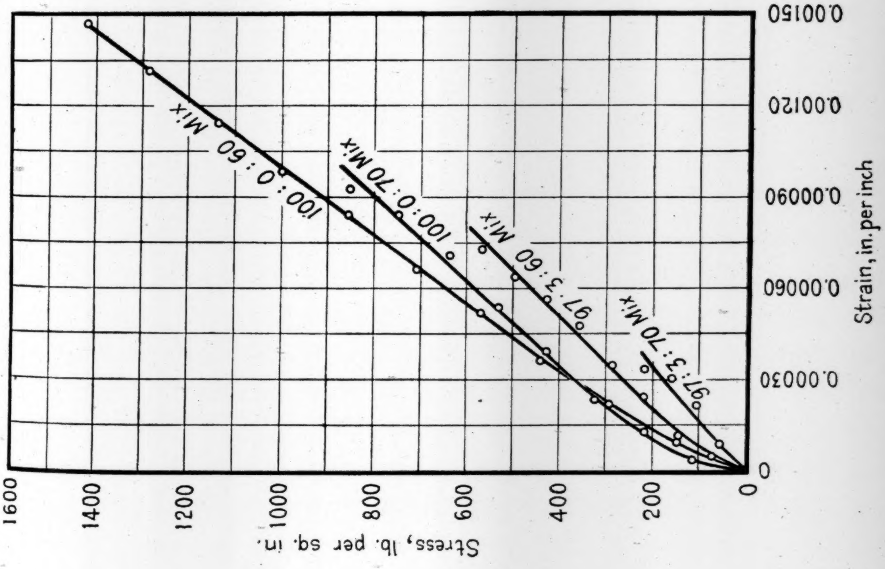

FIG. 2.—Stress-Strain Curves for Gypsum I Mixes.

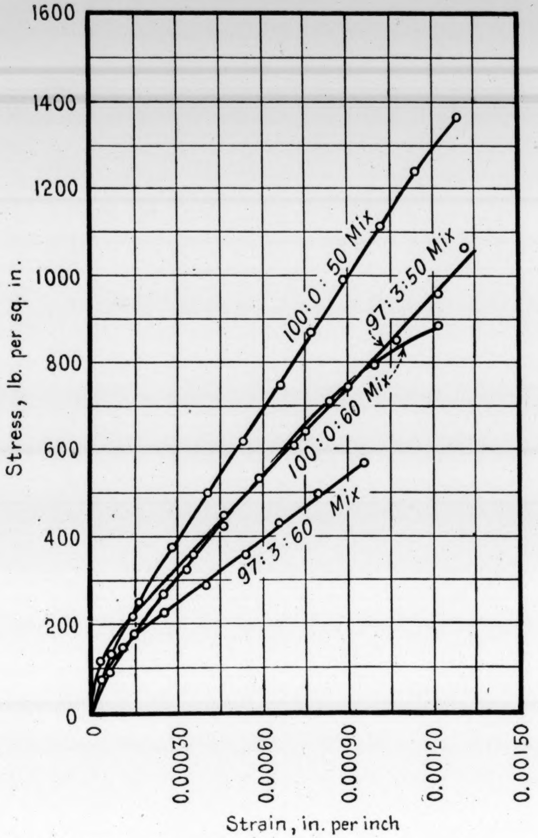

FIG. 4.—Stress-Strain Curves for Gypsum II Mixes.

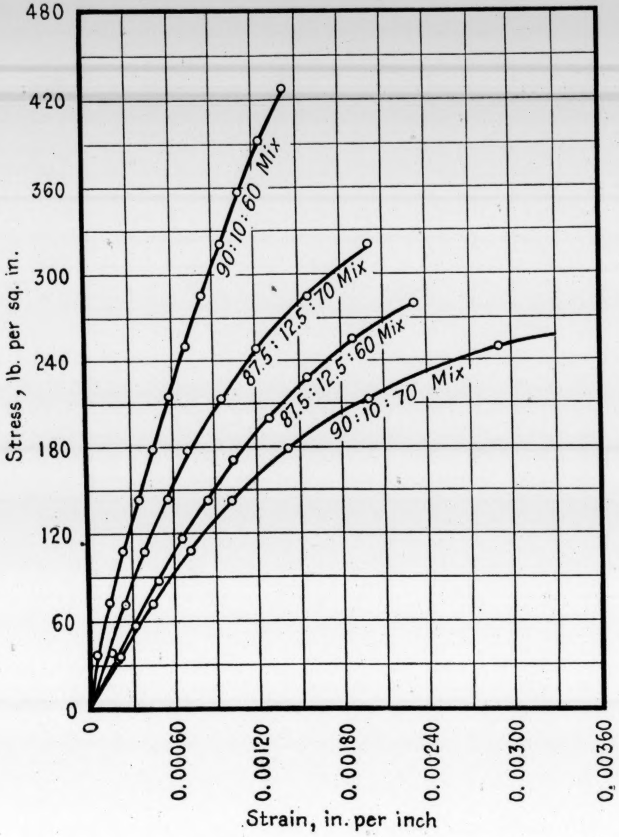

FIG. 5.—Stress-Strain Curves for Gypsum II Mixes.

In the majority of cases the modulus of elasticity increases when the water content for a given mix is decreased. The results of the tests indicate that in general the elastic modulus is approximately proportional to the compressive strength and since experience has shown that the strength decreases with increasing amounts of mixing water it is not to be expected that the elastic moduli will vary inversely. A second and more comprehensive series of tests was made, designed to eliminate as far as possible any variation in specimens due to method of mixing, casting, etc.

TABLE VI.—MODULUS OF ELASTICITY OF GYPSUM FIBER CONCRETE (DRIED AT 100° F.).

	Modulus of Elasticity, lb. per sq. in.	
Mix — Gypsum I	Initial Tangent	Secant
100:0:60	1 320 000	1 070 000
100:0:70	1 700 000	1 280 000
97:3:60	1 350 000	970 000
97:3:70	520 000	510 000
90:10:70	310 000	290 000
90:10:80	300 000	250 000
87.5:12.5:70	190 000	170 000
87.5:12.5:80	260 000	270 000
Gypsum II		
100:0:50	1 540 000	1 200 000
100:0:60	1 180 000	970 000
97:3:50	1 480 000	1 040 000
97:3:60	1 360 000	930 000
90:10:60	510 000	380 000
90:10:70	160 000	150 000
87.5:12.5:60	180 000	170 000
87.5:12.5:70	290 000	260 000

SERIES NO. 2: TESTS OF SPECIMENS CUT FROM SLABS.

Outline of Tests:

The second series of tests was made mainly on specimens cut from cast slabs. Figure 6 shows the procedure in detail. Only a few cast cylinders were made and tested for comparison purposes. A large mix, some 400 to 600 lb., was made at one time. From this mix a slab 7 by 18 by 40 in. and six of the standard 6 by 12-in. cylinders were cast. Another 6 by 12-in. cylinder which rested on plaster board rather than on the steel plate was used for a slump test, the mold being removed immediately after filling.

Three of the cylinders were used to obtain data on a "field test" by drying rapidly and testing at the end of 7 days. The other three were reserved for later tests.

The slab was cut into three bars, 4 by 4 by 36 in., which were used for transverse strength and deflection measurements, and one bar, 3 by 4 by 36 in., which was reserved as an "extra." The cutting

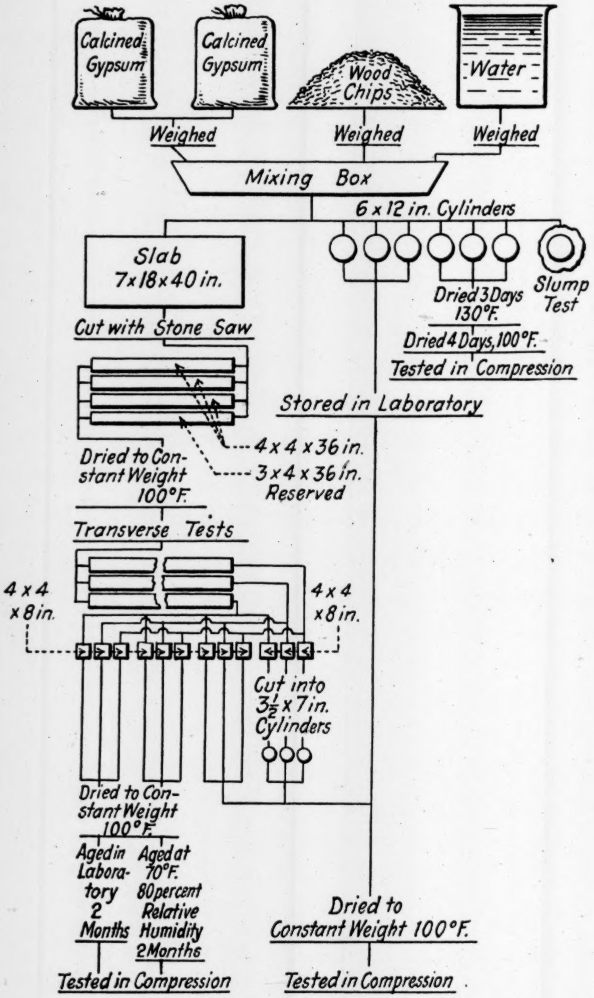
Calcined Gypsum
Calcined Gypsum
Wood Chips
Water
Weighed
Weighed
Weighed
Mixing Box
6 x 12 in. Cylinders
Slab 7x18x40 in.
Slump Test
Dried 3 Days 130°F.
Dried 4 Days, 100°F.
Tested in Compression
Cut with Stone Saw
Stored in Laboratory
4 x 4 x 36 in.
3 x 4 x 36 in. Reserved
Dried to Constant Weight 100°F.
Transverse Tests
4 x 4 x 8 in.
4 x 4 x 8 in.
Cut into 3½ x 7 in. Cylinders
Dried to Constant Weight 100°F.
Aged in Laboratory 2 Months
Aged at 70°F. 80 percent Relative Humidity 2 Months
Dried to Constant Weight 100°F.
Tested in Compression
Tested in Compression

FIG. 6.—Diagram of Test Procedure in Series No. 2.

was done in such a manner that all the surfaces were "cut surfaces," that is, no surface of the original slab was a surface of any of the specimens.

Two pieces approximately 4 by 4 by 18 in. resulted from the transverse test of each bar. Each of these was cut into two prisms

4 by 4 by 8 in. In general, there were twelve of these prisms obtained from each slab. Three of the prisms were dried to constant weight at 100° F., then aged in the laboratory air for about two months until the weight had become constant. Three other prisms after being dried at 100° F. were aged in a room maintained at 70° F. and 80 per cent relative humidity, for 2 months. Both sets of prisms were then tested in compression.

From three of the six remaining 4 by 4 by 8-in. prisms, cylinders $3\frac{1}{2}$ by 7 in. were cut. These, with the remaining three prisms (4 by 4 by 8 in.) and the three remaining 6 by 12-in. cylinders were dried to constant weight at 100° F. and tested in compression.

This series of tests was designed to obtain the following data:

1. The compressive strengths of specimens dried at 100° F.;
2. The effect of storage conditions on the compressive strength;
3. The relation between the compressive strengths of cut specimens of two different shapes;
4. The modulus of rupture of specimens dried at 100° F.;
5. The modulus of elasticity of specimens dried at 100° F.; and
6. The relation between the results of 7-day "field tests" and the laboratory tests.

Materials Used:

The materials used in this series were obtained from the same mills as in Series No. 1. The first shipment for use in this series was insufficient to complete all of the work, due to experimental difficulties mentioned later, and a second lot was therefore necessary. The properties of the calcined gypsum used in this latter series are given in Table VII. The wood chips were similar to those used in Series No. 1.

Construction of Specimens:

The large slab was cast in an oiled wooden mold, 7 by 18 by 40 in. inside dimensions. The companion 6 by 12-in. cylinders were cast in oiled steel molds, resting on machined steel plates. In making these specimens, sufficient material was mixed at one time to fill all the molds. The calcined gypsum, chips, and water were weighed out separately and thoroughly mixed. The molds were then filled as rapidly as possible. Three men were required to mix and cast the specimens, the whole operation being finished in from 6 to 8 minutes after adding the water.

It was found impossible to keep the mixing box entirely free from set gypsum, and after the first four batches had been cast, the fifth batch set before it could be placed in the molds. It was therefore necessary to duplicate this batch as well as two others in which the material had stiffened appreciably before casting. The construction of these duplicates required the additional shipment of material designated as "B" in Table VII. Small amounts of retarder were used in all the later mixes. Subsequently, as a matter of information, small scale tests were made to determine how long the gypsum fiber concrete could be worked without the loss of appreciable strength.

TABLE VII.—PROPERTIES OF CALCINED GYPSUMS USED FOR GYPSUM FIBER CONCRETE IN SERIES NO. 2.[a]

Gypsum	Gypsum I, Kettle Calcined		Gypsum II, Rotary Calcined	
	First Shipment	Second Shipment	First Shipment	Second Shipment
Testing consistency, per cent	69	57	49	50
Time of set, minutes	20	15	18	16
Tensile strength, lb. per sq. in.	260	290	310	320
Fineness:				
Retained on No. 30 sieve, per cent	0	0	0	2
Passing No. 30, retained on No. 100 sieve, per cent	14	15	19	20
Passing No. 100 sieve, per cent	86	85	81	78
Chemical Analyses:				
Silica (SiO_2) and insoluble matter, per cent	1.0	0.4	6.4	6.6
Lime (CaO), per cent	38.4	38.2	35.0	35.3
Sulfur trioxide (SO_3), per cent	54.1	53.8	44.5	44.8
Combined water (loss at 220° C.), per cent	6.0	6.5	4.1	4.3
Calcined gypsum ($CaSO_4 . \frac{1}{2}H_2O$) (calculated from H_2O), per cent	96.7	...	66.2	68.5
Calcined gypsum ($CaSO_4 . \frac{1}{2}H_2O$) (calculated from SO_3), per cent	...	97.3	...	...

[a] The second shipment of Gypsum I was used in the 97:3:60 and 97:3:70 mixes; the second shipment of Gypsum II was used in the 100:0:50 and 100:0:60 mixes. In all the other mixes the gypsum used was from the first shipment.

TABLE VIII.—EFFECT OF WORKING GYPSUM FIBER CONCRETE MIXES.

TIME ELAPSED BEFORE MOLDING	COMPRESSIVE STRENGTH, LB. PER SQ. IN.
2 minutes	1015
3 "	1000
4 "	1165
5 "	960
6 "	920
7 "	1080

A large batch, a 97:3 composition, was mixed with sufficient water to bring it to standard testing consistency and two 3 by 6-in. cylinders were cast 2 minutes after mixing and at one-minute intervals thereafter, until the material was too stiff to be forced into the mold, even by using considerable pressure. A typical set of results is given in Table VIII.

The material for the specimens at 6 and 7 minutes had to be forced into the mold. Similar results have been obtained using retarded mixes with longer time intervals between the casting of the specimens, and using mixes containing other proportions of wood chips. It seems evident, therefore, that no weakening of the set gypsum occurs when the materials may be molded or formed without exerting undue pressure.

Two hours after casting, the specimens were removed from the molds and brought to the laboratory for weighing and drying. The "field test" specimens were placed at once in the drying oven, the other specimens were aged about 2 months before undergoing any further treatment.

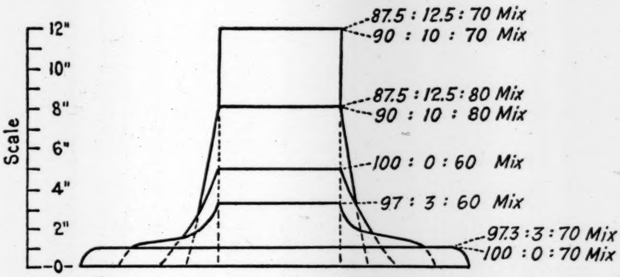

FIG. 7.—Diagram of Slump Tests of Gypsum I.

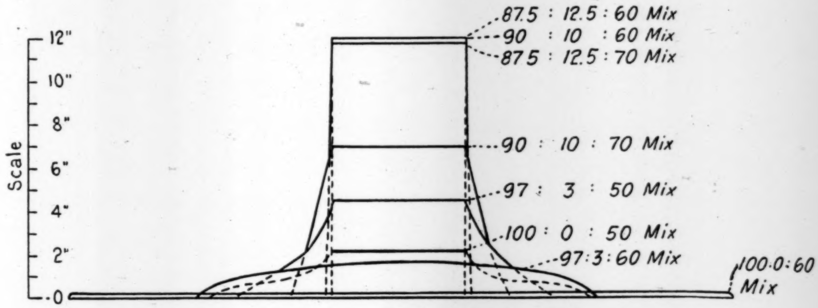

FIG. 8.—Diagram of Slump Tests of Gypsum II.

In this connection it may be of interest to note that the 6 by 12-in. cylinders required about 6 weeks to reach constant weight in the laboratory air, while the large slabs required approximately 2 months.

Slump Tests:

As stated above, slump tests were made on each batch to obtain data from which the consistencies could, if necessary, be duplicated later. The concrete was poured into a 6 by 12-in. cylinder resting on plaster board, rodded in the usual manner, and the cylinder removed, raising it vertically with precautions taken to prevent jarring of the specimen. The material was allowed to set, and the dimensions measured. The average cross-sectional form of each is shown in Figs. 7 and 8.

TABLE IX.—RESULTS OF TESTS OF GYPSUM FIBER CONCRETE SPECIMENS.

Proportion of Mix by Weight	Compressive Strength													Modulus of Rupture	Modulus of Elasticity
	6 by 12-in. Cylinders. Dried to constant weight at 100° F.	4 by 4 by 8-in. Prisms. Dried to constant weight at 100° F.		4 by 4 by 8-in. Prisms. Aged 2 months in laboratory air		4 by 4 by 8-in. Prisms. Aged 2 months at 70° F. and 80 per cent relative humidity		$3\frac{1}{2}$ by 7-in. Cylinders. Dried to constant weight at 100° F.			6 by 12-in. Cylinders for 7-Day Field Test.[a] Dried 3 days at 130° F. and 4 days at 100° F.		4 by 4 by 36-in. Bars. Dried to constant weight at 100° F.	4 by 4 by 36-in. Bars. Dried to constant weight at 100° F.
	lb. per sq. in.	lb. per sq. in.	Per cent of Column 1	lb. per sq. in.	Per cent of Column 2	lb. per sq. in.	Per cent of Column 2	lb. per sq. in.	Per cent of Column 1	Per cent of Column 2	lb. per sq. in.	Per cent of Column 1	lb. per sq. in.	lb. per sq. in.
	1	2		3		4		5			6		7	8
							Gypsum I, Kettle Calcined							
100:0:60....	1810	1560	86	1580	102	1300	84	1720	95	110	1390	77	480	900 000
100:0:70....	1370	1140	83	1040	91	950	83	1110	81	98	920	67	320	830 000
97:3:60....	910	910	100	900	98	760	84	860	94	94	810	88	230	850 000
97:3:70....	810	810	100	660	81	580	72	800	99	99	630	78	210	580 000
90:10:70...	580	630	109	560	88	520	82	590	101	33	500	87	180	370 000
90:10:80...	580	530	92	490	92	390	73	510	89	96	570	99	[c]	[c]
87.5:12.5:70	600	570	95	510	89	440	78	540	90	95	500	83	150	260 000
87.5:12.5:80	540	500	93	450	90	400	80	480	89	95	430	80	120	220 000
							Gypsum II, Rotary Calcined							
100:0:50....	2290	2070	90	1670	81	1390	67	2020	88	98	1620	70	400	1 120 000
100:0:60....	1760	1440	82	1150	80	1040	72	1610	91	112	1340	76	300	840 000
97:3:50....	1300	1320	102	1150	87	920	70	1340	104	102	730	56	310	770 000
97:3:60....	1010	910	90	820	89	670	74	940	93	103	560	55	240	650 000
90:10:60...	690	630	91	570	90	480	77	610	88	97	440	64	170	330 000
90:10:70...	550	490	90	440	89	340	70	500	90	100	460	83	150	250 000
87.5:12.5:60	410[b]	580	..	550	94	460	79	560	..	96	350[b]	..	170	300 000
87.5:12.5:70	450	440	98	430	97	360	81	420	94	95	320	72	110	200 000
Average.....	....	.....	93		90		77		92	99		76		

[a] These specimens were not dry. The results are not necessarily comparable with those in the other columns.
[b] All cylinders in this series were defective. They were badly honeycombed as the mix was too dry.
[c] Not determined.

Seven-Day Field Tests:

Three of the 6 by 12-in. cylinders were used for a "field test" such as would be necessary on a construction operation where it would not be desired to wait for the specimens to become entirely dry. The specimens were dried for 3 days at 130° F. and then for

4 days at 100° F. It was not considered advisable to heat for 7 days at the higher temperature as some calcination might occur. At the end of the 7 days, it was evident that while certain of the cylinders were dry, the majority still retained appreciable amounts of water. The ends of the specimens were ground plane and parallel and the compressive strength determined. The results are given in Table IX, column 6.

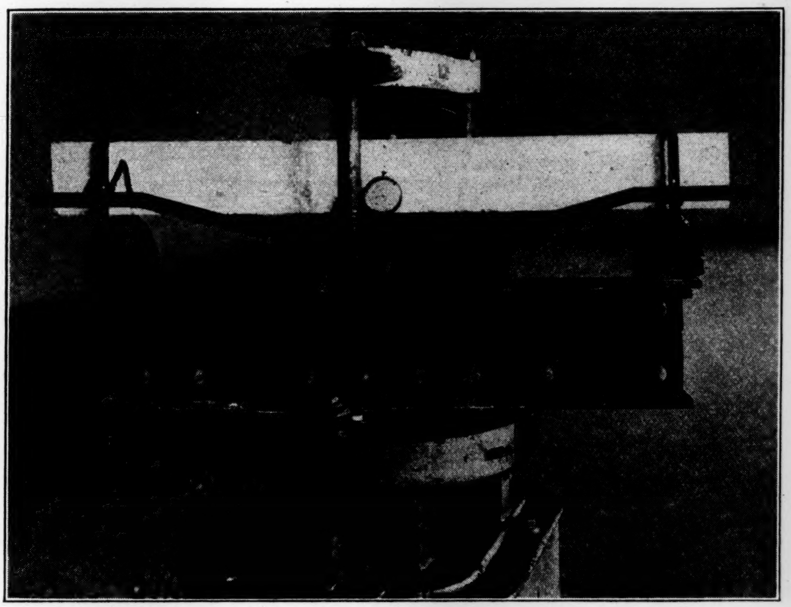

FIG. 9.—Apparatus Used in Flexure Tests.

Flexure Tests:

The flexural strength of the gypsum-fiber concrete was determined on specimens cut from the large slabs. Difficulty was experienced at first in obtaining a saw which would make a satisfactory clean cut. A 2-ft. circular wood saw was first tried, but it was dulled rapidly and its use would have necessitated sharpening after each cut. Successful results were obtained by using a stone saw. This consisted of a thin cast-iron disk, 2-ft. in diameter, faced with carborundum. Excellent cuts were made with this, using a large stream of water directed against the facing to keep the pores clean and to prevent dusting. Because of the water present, there was little temperature rise and there was no possibility of surface calcination, such as may occur during dry cutting. In many cases, chips which were approximately parallel to the direction of cutting were cut cleanly and no tearing was noticeable. The width of the cut was slightly over $\frac{1}{4}$ in.

Operating in this manner, three bars, 4 by 4 by 40 in., were cut from each slab. They were so cut that no face of the finished bar was part of the exterior surface of the slab. The ends of the three specimens were trimmed with a hand saw so the final size of the bars used for flexure tests was 4 by 4 by 36 in.

The specimens for the flexure test were dried to constant weight at 100° F. before testing. Figure 9 shows the apparatus used in testing. The specimens rested on two triangular prisms, with rounded vertices, placed 30 in. apart. Another knife edge, bearing on a small steel plate at the center of the specimen, was used in applying the load. The whole apparatus was mounted in a 2000-lb. capacity testing machine.

The deflection of the bar on loading was measured by a micrometer dial reading to 0.0001 in., attached as shown in Fig. 9. Two long brass arms rested on hangers over the knife edges. A lever, bearing against a piece of thin metal attached to the mid-point of the under side of the specimen, conveyed the motion of the center of the specimen to the dial.

Loads were applied in increments of 10, 25, or 50-lb., depending on the strength of the specimen; deflection measurements were taken after each load increment. Deflection readings were taken up to failure, the dial being protected from injury due to breaking of the specimen. The modulus of rupture calculated from the breaking load is given in column 7 of Table IX. In column 8 is given the modulus of elasticity.

The modulus of rupture, R', in pounds per square inch, was calculated from the equation:

$$R' = \frac{9}{32}\left(W + \frac{5}{2}p'\right)$$

where

p' = the applied load at failure, in pounds;

W = the weight of the specimen, in pounds.

The modulus of elasticity, E, in pounds per square inch, was calculated from the equation:

$$E = \frac{3375}{128}\frac{P}{Y}$$

where

P = the applied load, in pounds;

Y = the midspan deflection in inches, under the applied load P.

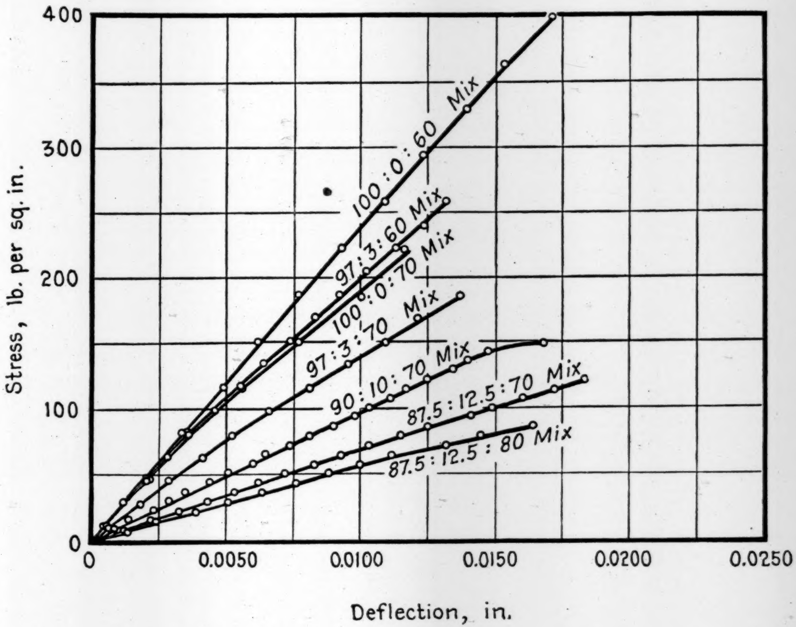

FIG. 10.—Deflection Curves for Gypsum I Mixes.

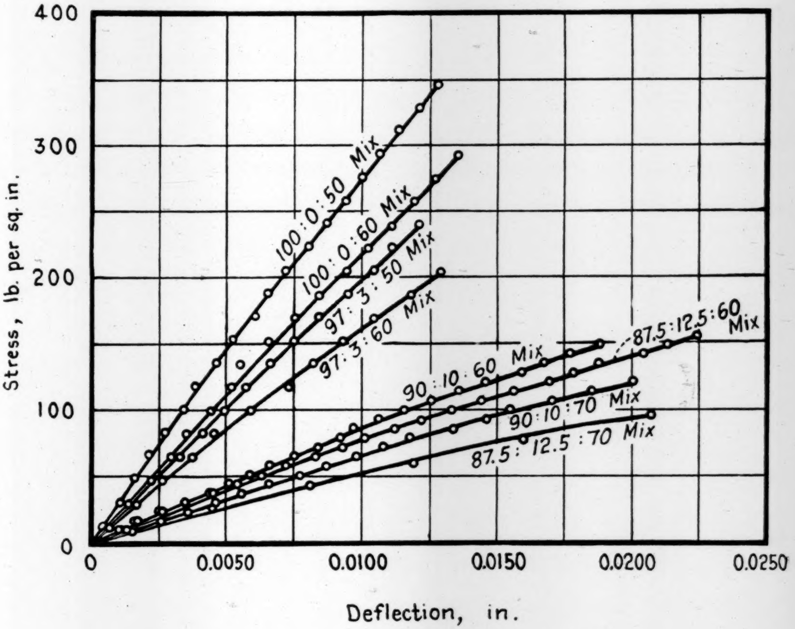

FIG. 11.—Deflection Curves for Gypsum II Mixes.

The values of stress plotted in Figs. 10 and 11 were calculated from the equation $R = \frac{9}{32}(W + \frac{5}{2} P)$ for values of P which were less than p'.

Compressive Strength:

The pieces remaining from the flexure tests were cut into 4 by 4 by 8-in. prisms. In general, twelve prisms were obtained from each of the original slabs, but in a few cases the fracture in the flexure test was so far from the middle of the span that one prism was lost. Three prisms from each group of twelve were turned into cylinders, 3½ in. in diameter and 7 in. in length. The cutting was done with a tube drill.

The three cut cylinders, together with three of the 4 by 4 by 8-in. blocks and the remaining three 6 by 12-in. cylinders were dried together in an oven at 100° F. until the weight was constant. The ends were then ground plane and parallel and the specimens broken in compression. The results, in pounds per square inch, are given in Table IX, columns 1, 2 and 5.

Six of the 4 by 4 by 8-in. prisms remained. These were dried to constant weight at 100° F. Three were then placed in a room at 70° F. and 80 per cent relative humidity, and three were aged in the laboratory. In about 2 months the weights had again become constant. The specimens were then broken in compression. The results are given in Table IX, columns 3 and 4.

It may be of interest to note that most of the specimens after drying to constant weight showed no appreciable gain during the two months' exposure. The specimens weighed from 1800 to 2600 g. and were weighed on balances sensitive to 5 g. A few specimens gained 10 g. while more gained 5 g. The results were rather erratic but indicated that in general the mixes containing the larger amounts of wood chips absorbed the greater amounts of moisture from the air.

RESULTS

A comparison of the data presented in Tables V and IX shows that the compressive strength as determined on the cast 6 by 12-in. cylinders is approximately the same for the two series, varying between 400 and 2000 lb. per sq. in. with varying compositions. The modulus of elasticity determined in the transverse tests of Series No. 2

compares well with the secant modulus in compression of Series No. 1, varying from 200,000 to 1,000,000 lb. per sq. in., depending upon the composition of the mix.

An interesting case is that of the 87.5:12.5:60 mix of Gypsum II in Series No. 2. As shown in Table IX, the compressive strength of the cylinders of this mix was less than that of the mix containing ten parts more water. All the other data indicate a decrease in strength with increased water content. This anomaly may be explained by the fact that the mix was a very dry one and the cast specimens were badly honeycombed and consequently weaker than normal. However, in casting the slab the honeycombing was prevented, so the cut specimens are all stronger than the cast cylinders. After these results had been obtained additional cylinders of this mix were cast, using particular care to prevent honeycombing. The strength of these when dried to constant weight at 100° F. was 530 lb. per sq. in., indicating that the weakening due to the porous structure had been partly overcome, but not entirely, as the specimens were still weaker than the cut specimens.

The compressive strengths of the 4 by 4 by 8-in. prisms and of the cut cylinders dried at 100° F. was somewhat less than that of the cast cylinders similarly dried, averaging 93 per cent and 92 per cent of the strength of the latter. There is practically no difference in strength between the cut specimens of the two different shapes.

The effect of moisture in the specimens is clearly shown in columns 3 and 4 of Table IX. Specimens dried to constant weight at 100° F. and then exposed to laboratory air for 2 months (August and September, 1928) averaged 10 per cent less in compressive strength than specimens not so exposed. Exposure to constant temperature and humidity, 70° F., 80 per cent relative humidity, for 2 months caused a decrease in strength of 23 per cent on the average.

It is believed that the storage conditions of gypsum fiber concrete structures will, in general, approximate the two conditions investigated. The air-dried specimens were stored at a high average temperature and a moderately high relative humidity (average noonday temperature during drying, 78° F., average noonday relative humidity, 66 per cent). Those stored in the constant temperature room represent medium temperature and high humidity conditions. Increases in storage temperatures and decreases in relative humidities would be expected to produce greater strengths. It will be noted that the results of the "field tests" were about the same as the results obtained with the specimens stored at 70° F. and 80 per cent relative humidity.

CONCLUSIONS

The investigation has developed the following:

1. (*a*) Gypsum fiber concrete with 3 per cent chips, of the consistencies used in practice, had a compressive strength of from 800 to 1300 lb. per sq. in.

(*b*) Gypsum fiber concrete with 12.5 per cent chips, of the consistencies used in practice, had a compressive strength of from 450 to 600 lb. per sq. in.

2. Specimens tested after storage at 70° F. and 80 per cent relative humidity showed strengths averaging 77 per cent of the bone dry strengths.

3. Cut cylinders and cut prisms had equal strengths.

4. (*a*) Gypsum fiber concrete with 3 per cent chips, of the consistencies used in practice, had a modulus of rupture from 210 to 310 lb. per sq. in.

(*b*) Gypsum fiber concrete with 12.5 per cent chips, of the consistencies used in practice, had a modulus of rupture from 110 to 170 lb. per sq. in.

5. (*a*) Gypsum fiber concrete with 3 per cent chips, of the consistencies used in practice, had a modulus of elasticity from 580,000 to 850,000 lb. per sq. in.

(*b*) Gypsum fiber concrete with 12.5 per cent chips, of the consistencies used in practice, had a modulus of elasticity from 200,000 to 300,000 lb. per sq. in.

6. A 7-day test under suitable drying conditions can be used to indicate the quality of the materials employed.

Acknowledgment:

The materials used in this investigation were furnished through the courtesy of the United States Gypsum Co., the former Beaver Products Co., and the H. E. Marks Corp. The chemical analyses reported herein were made by R. B. Rudy of the U. S. Bureau of Standards. Acknowledgment is also made of the assistance rendered in the casting of the specimens by H. F. McMurdie and M. C. Dailey.

REPORT OF COMMITTEE D-1

ON

PRESERVATIVE COATINGS FOR STRUCTURAL MATERIALS

Committee D-1 on Preservative Coatings for Structural Materials held a meeting in Atlanta, Ga., on April 10, 1930.

Since the last annual meeting, eight new members have been elected and eleven resignations have been accepted, leaving a total membership of 176.

The work of the committee has progressed in a satisfactory manner along many lines of activity over which the committee has jurisdiction and the work of the past year has resulted in the following recommendations:

I. Five new tentative specifications are being submitted;

II. Revisions for immediate adoption are proposed in two standard specifications and one standard method of test;

III. The revision of four tentative specifications and one tentative method of test is proposed;

IV. The revision and advancement to standard of one tentative method of test is proposed;

V. The withdrawal of two standard specifications and one standard method is recommended.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

In this report, recommendations affecting standards and tentative standards are noted in brief form together with the results of the letter ballot. These recommendations are explained in greater detail in the reports of the subcommittees which are directly responsible for them.

I. *Proposed Tentative Standards.*—The committee submits for publication as tentative, the following five new specifications as appended hereto:[1]

Proposed Tentative Specifications for Glazier's Putty, recommended by Subcommittee XV;

Proposed Tentative Specifications for Amyl Alcohol (Synthetic), recommended by Subcommittee XXV;

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[1] See pp. 1065 to 1084, inclusive.—Ed.

Proposed Tentative Specifications for Amyl Acetate (Synthetic), recommended by Subcommittee XXV;

Proposed Tentative Specifications for Butyl Propionate (90 to 93 Per Cent Grade), recommended by Subcommittee XXV;

Proposed Tentative Specifications for Ethyl Lactate (Synthetic), recommended by Subcommittee XXV.

II. *Proposed Revisions of Standards.*—The committee recommends that the following two standard specifications and one standard method of test be revised as given in detail in the reports of the subcommittees and continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption:

Standard Specifications for Lampblack (D 209 – 26), revised as recommended by Subcommittee XV;

Standard Specifications for Bone Black (D 210 – 26), revised as recommended by Subcommittee XV;

Standard Methods of Routine Analysis of White Pigments (D 34 – 27), revised as recommended by Subcommittee VIII.

III. *Proposed Revisions of Tentative Standards.*—The committee recommends that the following four tentative specifications and one tentative method of test be revised as given in detail in the reports of the subcommittees and continued as tentative:

Tentative Specifications for Soluble Nitrocellulose (D 301 – 29 T), revised as recommended by Subcommittee XXV;

Tentative Specifications for Ethyl Acetate (85 to 88 per cent Grade) (D 302 – 29 T), revised as recommended by Subcommittee XXV;

Tentative Specifications for Butyl Acetate (85 to 88 per cent Grade) (D 303 – 29 T), revised as recommended by Subcommittee XXV;

Tentative Specifications for Butanol (Normal Butyl Alcohol) (D 304 – 29 T), revised as recommended by Subcommittee XXV;

Tentative Methods for Sampling and Testing Lacquer Solvents and Diluents (D 268 – 29 T), revised as recommended by Subcommittee XXV.

IV. *Tentative Standard Revised and Advanced to Standard.*—The committee recommends that the Tentative Methods of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (D 307 – 29 T) be revised and advanced to standard as proposed by Subcommittee XVIII.

V. *Withdrawal of Standards.*—The committee recommends that the Standard Specifications for Dry Bleached Shellac (D 207 – 26), the Standard Specifications for Orange Shellac (D 237 – 27) and the

Standard Methods of Testing Shellac (D 29 - 25) and for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) (D 29 - 28) be withdrawn as proposed by Subcommittee XIII.

VI. *Tentative Standards Continued as Tentative.*—In addition to the recommendations affecting the tentative standards mentioned in this report, there are a number of additional tentative standards under the jurisdiction of the committee not specifically mentioned in the report or in the subcommittee reports. The committee recommends that these tentative standards be continued without revision.

The above recommendations have been submitted to letter ballot of the committee, which consists of 176 members; 68 members returned their ballots. The analysis of the vote of the committee is given in the following table:

Items	Affirmative	Negative	Not Voting
I. NEW TENTATIVE STANDARDS			
Specifications for Glazier's Putty	57	0	11
Specifications for Amyl Alcohol (Synthetic)	48	0	20
Specifications for Amyl Acetate (Synthetic)	48	0	20
Specifications for Butyl Propionate (90 to 93 per cent Grade)	48	1	19
Specifications for Ethyl Lactate (Synthetic)	48	1	19
II. PROPOSED REVISIONS OF EXISTING STANDARDS			
Specifications for Lampblack (D 209 - 26), immediate adoption	58	0	10
Specifications for Bone Black (D 210 - 26), immediate adoption	58	0	10
Methods of Routine Analysis of White Pigments (D 34 - 27), immediate adoption	54	0	14
III. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Specifications for Soluble Nitrocellulose (D 301 - 29 T)	49	0	19
Specifications for Ethyl Acetate (85 to 88 per cent Grade) (D 302 - 29 T)	48	1	19
Specifications for Butyl Acetate (85 to 88 per cent Grade) (D 303 - 29 T)	48	1	19
Specifications for Butanol (Normal Butyl Alcohol) (D 304 - 29 T)	48	1	19
Methods for Sampling and Testing Lacquer Solvents and Diluents (D 268 - 29 T)	47	0	21
IV. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Methods of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (D 307 - 29 T), as revised	50	1	17
V. WITHDRAWAL OF STANDARDS			
Specifications for Dry Bleached Shellac (D 207 - 26)	46	0	22
Specifications for Orange Shellac (D 237 - 27)	46	0	22
Standard Methods of Testing Shellac (D 29 - 25) and for Determination of Wax in Shellac (D 29 - 28)	46	0	22

ACTIVITIES OF SUBCOMMITTEES

Appended hereto are reports of the following subcommittees:

Subcommittee VII on Accelerated Tests for Protective Coatings;

Subcommittee XXV on Cellulose Ester Coatings.

In addition to the subcommittee reports appended, the activities of other subcommittees are reported as follows:

Special Committee to Consider Specifications for Railroad Paints

(G. W. Thompson, chairman).—A meeting of the special committee appointed to consider the question of paint specifications for railroads was held in Atlantic City, N. J., at the time of the annual meeting in June, 1929. There were present Messrs. M. E. McDonnell, Pennsylvania R.R., H. E. Smith, New York Central R.R., H. A. Gardner, L. P. Nemzek, E. C. Holton and G. W. Thompson (chairman). After considerable discussion it was the expressed sense of the meeting that it would be impracticable to establish a permanent subcommittee on specifications for railroad paints. The committee, however, believed that an endeavor should be made to obtain from those connected with railroad companies a number of papers covering particular problems with which they are confronted in their painting work. These papers might be in the nature of a symposium or a number of papers presented at several annual meetings.

Report of Subcommittee VIII on Methods of Analysis of Paint Materials (F. W. Smither, chairman).—Subcommittee VIII held two meetings during the past year. A program was formulated and cooperative studies carried out on methods for determining the hiding power of paints and pigments and the tinting strength of pigments. A summary prepared from the reports of the cooperators is appended hereto. The subcommittee will continue these studies during the coming year.

The subcommittee recommends that the Standard Methods of Routine Analysis of White Pigments (D 34 – 27)[1] be revised as follows, and that the methods, as revised, be continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Basic Sulfate of Lead.—In the section on "Determination of Total Lead" after the third sentence, add a new sentence to read as follows:

> Calculate the percentage of total lead.

In the section on "Determination of Total Zinc," change the third sentence from its present form: namely,

> Calculate the zinc to ZnO, as follows:

to read as follows:

> Calculate the total zinc to percentage of ZnO, and then calculate the percentage of PbO and $PbSO_4$, as follows:

The subcommittee recommends that the six tentative methods under its jurisdiction which have been standing for one or two years, be continued as tentative without revision.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 305.

Report of Subcommittee XIII on Shellac (J. W. Paisley, chairman).—This subcommittee believes that additional work should be carried out on the Tentative Methods of Sampling and Testing Shellac (D 29 - 29 T) before advancing them to standard, and therefore recommends that these methods be continued as tentative. The subcommittee also recommends that the Tentative Specifications for Dry Bleached Shellac (D 207 - 29 T) and Tentative Specifications for Orange Shellac (D 237 - 29 T) be continued as tentative without revision pending possible modification which may be desirable after perfection of the Tentative Methods D 29 - 29 T.

The subcommittee further recommends that the Standard Specifications for Dry Bleached Shellac (D 207 - 26)[1], the Standard Specifications for Orange Shellac (D 237 - 27)[2] and the Standard Methods of Testing Shellac (D 29 - 25)[3] and for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) (D 29 - 28)[4] be withdrawn.

Subcommittee XV on Specifications for Pigments Dry and in Oil When Marketed in That Form (H. E. Smith, chairman).—During the past year this subcommittee has considered certain minor details in two existing standard specifications and has prepared one new specification, the Proposed Specifications for Glazier's Putty, which the subcommittee recommends for publication as tentative, as appended hereto.[5]

Standard Specifications for Lampblack (D 209 - 26)[6] *and Standard Specifications for Bone Black (D 210 - 26)*[7].—It has been found that the present maximum limit of 0.5 per cent extractive matter in these two specifications is unreasonably low, good commercial blacks sometimes containing more than this percentage. The committee believes that this requirement should be increased to 2.0 per cent. It has also been found that the requirement that the extract be colorless is not practicable, blacks of good quality sometimes yielding a colored extract. Experiments by the U. S. Bureau of Standards and others also indicate acetone to be the preferable extraction solvent and in addition it is free from the poisonous character of benzol. The subcommittee therefore recommends for immediate adoption by nine-tenths vote the following revision of the Standard Specifications D 209 - 26 and D 210 - 26:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 239.

[2] *Ibid.*, p. 241.

[3] *Ibid.*, p. 292.

[4] 1928 Supplement to Book of A.S.T.M. Standards, p. 117.

[5] See p. 1065.—ED.

[6] 1927 Book of A.S.T.M. Standards, Part II, p. 259.

[7] *Ibid.*, p. 261.

Section 3 (b).—Change the extraction requirement in the table from its present form: namely,

Benzol extract (which must be colorless), maximum, per cent..........0.5

to read as follows:

Acetone extract, maximum, per cent..................................2.0

Subcommittee XVIII on Physical Properties of Materials (F. P. Ingalls, chairman).—This subcommittee recommends that the Tentative Method of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units (D 307 - 29 T)[1] be revised as follows and advanced to standard:

Introductory Paragraph.—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

The appearance of a painted surface may, however, be influenced by properties [in addition to color] ***other than spectral reflectance***, notably, degree of gloss.

Section 2.—Change the last sentence from its present form: namely,

The reflection factor of the standard reflecting surface shall be tentatively assumed as 98 per cent.

to read as follows:

If this standard is used, it shall be tentatively assumed to have a reflection actor of 98 per cent. If any other surface is used as the standard, its reflection shall be specified.

Section 3.—Change from its present form: namely,

3. The sample and standard shall be illuminated under identical conditions.

NOTE.—Diffuse illumination offers the most generally reproducible method of illuminating both sample and standard. It is recommended that for an intercomparison of results this type of illumination be used.

to read as follows:

3. (*a*) The sample and standard shall be illuminated under identical conditions.

(*b*) The manner of illumination shall be specified, stating whether the illumination is diffuse or uni-directional. If uni-directional, the angle of incidence shall be specified.

(*c*) The manner and angle of viewing shall be specified.

NOTE.—This method (measurement of spectral reflectance) serves to specify the color of a painted surface in fundamental physical terms, subject to the limitation that the color may depend upon the manner of illumination. In addition to selectivity of reflectance with respect to wave length, the appearance of such a surface and particularly its changing appearance with different manners of illumination and different angles of view, depends upon the gloss of the surface. The manner of illumination must accordingly be made a part of the specification. Unless it is otherwise specified for some particular purpose for which the measurements are being made, it is recommended that the sample be illuminated diffusely and viewed in the direction normal to its surface. If the purpose of the measurements is to provide a specification of the color of a surface viewed without glare due to gloss of the surface, the specularly reflected light shall be excluded. Where the appearance of a painted surface is to be completely specified, inclusion of degree of gloss of that surface is necessary. In every case it shall be definitely stated whether or not the reflected light measured includes light reflected specularly from the surface of the sample.

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[1] ***Proceedings***, **Am. Soc. Testing Mats., Vol. 29, Part I, p. 678 (1929);** also 1929 Book of A.S.T.M. **Tentative Standards, p. 336.**

Section 4 (a).—Change the word "measurement" to read "measuring."

Section 7.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

7. If the sample [visibly] undergoes a *visible* change during the analysis, the readings shall be rejected. (See [Note], Section [3] *5* (*a*).)

Section 8 (c).—Change from its present form: namely,

(*c*) The character of the illumination as specified in Section 3 (*a*).

to read as follows:

(*c*) The manner of illumination and manner of viewing as specified in Section 3 (*b*) and (*c*).

Subcommittee XXIII on Anti-Fouling Paints (A. M. Muckenfuss, chairman).—This subcommittee recommends that the Tentative Specifications for the Toxic Ingredients in Anti-Fouling Paints (D 277 - 28 T) be continued as tentative.

The election of officers for the ensuing term of two years resulted in the selection of Allen Rogers, chairman; C. S. Neal, vice-chairman, and P. H. Cathcart, secretary.

This report has been submitted to letter ballot of the committee, which consist of 176 members; 68 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

ALLEN ROGERS,
Chairman.

R. L. HALLETT,
Secretary.

EDITORIAL NOTE

The proposed Tentative Specifications for Glazier's Putty; for Amyl Acetate (Synthetic); for Butyl Propionate (90 to 93 per cent Grade); and for Ethyl Lactate (Synthetic) were accepted for publication as tentative and appear on pages 1065, 1078, 1084, and 1081, respectively.

The proposed Tentative Specifications for Amyl Alcohol (Synthetic) were accepted at the annual meeting for publication as tentative. Additional revisions of these specifications were subsequently approved on August 12 by Committee E-10 on Standards. The specifications in their revised form appear on page 1079.

The proposed immediate revisions of the Standard Specifications for Lampblack and for Bone Black and of the Standard Methods of Routine Analysis of White Pigments were approved at the annual meeting by a unanimous vote and were subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications and methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 319, 321 and 367, respectively.

The proposed revisions of the Tentative Specifications for Ethyl Acetate (85 to 88 per cent Grade); for Butyl Acetate (85 to 88 per cent Grade), and for Butanol (Normal Butyl Alcohol) were accepted. The tentative specifications in their revised form appear on pages 1080, 1082, and 1083.

The proposed revisions of the Tentative Specifications for Soluble Nitrocellulose and of the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents were accepted at the annual meeting. Additional revisions of these specifications and methods were subsequently approved on August 12 by Committee E-10 on Standards. The specifications and methods in their revised form appear on pages 1067 and 1085.

The Tentative Methods of Analysis for the Color Characteristics of Paints in Terms of Fundamental Physical Units, as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, page 437.

The withdrawal of the Standard Specifications for Dry Bleached Shellac and for Orange Shellac, and of the Standard Methods of Testing Shellac and for Determination of Wax in Shellac ("Machine-Made" and Dry-Bleached Refined Shellac) was approved.

REPORT OF SUBCOMMITTEE VII ON ACCELERATED TESTS FOR PROTECTIVE COATINGS

One meeting of Subcommittee VII has been held during the past year. At this meeting the following topics were discussed:

1. A Suggested Method for Quantitative Determination of the Protective Properties of Metal Preservative Paints. The method developed by Mr. W. O. Snelling was described by him, and individual members agreed to investigate this method during the year. No reports have been received.

2. The Use of the Microscope in Making Observations and Photographically Recording Paint, Varnish and Lacquer Films. This consists of a discussion of the correlated report of individual work by various laboratories during 1928 and 1929.

3. Standard Wood Panels for Cooperative Test Work. It was decided to distribute and test a laminated ply wood that had shown some promise in preliminary tests. However, the supply of this wood that was subsequently received proved to be unsatisfactory, and the cooperative tests have been held up pending further investigation.

The subcommittee has no definite progress to report on quantitative evaluation of paint failures on wood although it is known that a number of investigators are seriously considering this problem.

The subcommittee has not attempted any further cooperative tests to compare the different weathering units in use throughout the country. Contacts, however, are being made with groups of laboratories, many of them outside the membership of the committee, who are making such comparisons among themselves. These laboratories have kindly consented to make the information obtained from their tests available to the subcommittee.

The subcommittee plans to continue work along the lines mentioned above, with immediate attention to the partially completed program for establishing a standard grade of wood for test panels for accelerated weathering tests. In addition, the subcommittee will continue its policy, stated in its report last year, of encouraging individual research work on subjects that have a bearing on the problems in which it is interested.

Respectfully submitted on behalf of the subcommittee,

H. A. Nelson,
Chairman.

APPENDIX

REPORT OF COOPERATIVE WORK ON THE DETERMINATION OF HIDING POWER OF PAINTS AND PIGMENTS AND THE TINTING STRENGTH OF PIGMENTS[1]

This test program, carried on in cooperation with the work of Subcommittee VIII on Methods of Analysis of Paint Materials, called for sending out a series of pigment samples and pigment-in-oil mixtures, with the suggestion that the cooperators test these samples in any way they saw fit, with special emphasis on tinting strength and cryptometer determinations. It was requested that each laboratory test the pigments in accordance with the procedure for tinting strength described in the former Tentative Method of Test for Mass Color and Tinting Strength of Pigments (D 282 – 28 T).[2] The bone black and sampling oil were supplied for this test.

The work and discussion established the following tentative conclusions: (1) that the former A.S.T.M. Tentative Method D 282 – 28 T for tinting strength did not give consistent results; (2) that tinting strength was a factor of considerable significance and tests for its measurement should be studied further by the subcommittee; and (3) that hiding power can be measured, and that the cryptometer gives satisfactory results, quite reproducible by the several laboratories using the pigment-oil mixtures.

The subcommittee also agreed on the following tentative working definition for hiding power:

> "*Hiding Power.*—The hiding power of a paint is measured by that quantity of a paint that must be applied to a given area of an impervious black and white background, the white portion of which has a brightness of 80 ± 2 per cent, and the black to be less than 8 per cent brightness, so as to bring the brightness over the black background to within 98 per cent of that over the white background, and shall be specified as wet or dry."

Reports have been submitted by the following organizations: U. S. Bureau of Standards, E. I. duPont de Nemours and Co., New Jersey Zinc Co. Research Laboratories, Henry A. Gardner Laboratory,

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[1] Attention is also called to several papers dealing with hiding power presented before this annual meeting, namely, "Hiding Power Measurements in Theory and Application," by A. H. Pfund, "A Discussion of Hiding Power and Its Measurement," by G. F. A. Stutz, Jr., and G. S. Haslam, and "A Practical Brush-Out Test for Hiding Power of Paints," by H. A. Gardner, G. G. Sward and S. A. Levy, see *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, pp. 878 to 894 (1930).

[2] This tentative method which was discontinued in 1929 appeared in *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 885 (1928).

Pratt and Lambert, Ault and Wiborg, and the Department of Physics of Johns Hopkins University.

The following table shows the list of cooperators and the tests made by them:

Laboratory	Tinting Strength		Hiding Power	
	A.S.T.M. Method D 282 - 28 T[a]	Preferred Practice	Cryptometer	Other Tests
U. S. Bureau of Standards	✓	..	✓	Dry hiding power by Bruce method
E. I. duPont de Nemours and Co.	✓	✓[b]	✓	Single coat hiding
New Jersey Zinc Co.	✓	✓	✓	Spinning film test
Henry A. Gardner Laboratory	✓	..	✓	Brush-out method
Pratt and Lambert	..	✓	✓	Brush-out method
Ault and Wiborg	..	✓	..	Opacity test
Johns Hopkins Univ., Physics Dept.	..	..	✓	Black and white cryptometer

[a] The former Tentative Method of Test for Mass Color and Tinting Strength of Pigments (D 282 - 28 T), since discontinued, see *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 885 (1928).

[b] Tests made by two laboratories.

TABLE I.—RESULTS OF HIDING POWER TESTS.

	Tests on Paints After Drying, Results in sq. ft. per gallon		Tests on Pigment After Drying, Results in sq. ft. per pound of pigment		
	Bureau of Standards, Bruce Method	Pratt and Lambert, Brush-Out Method	Bureau of Standards Bruce Method	Pratt and Lambert, Brush-Out Method	Ault and Wiborg, Opacity Test Procedure[a]
Basic carbonate white lead	322	204	16	9.78	100
ZnO	298	232	27	21.1	167
Lithopone	350	257	30	21.4	167
Titanox	483	415	39	33.5	200
ZnS	608	517	56	48.1	267
TiO_2	645	482	63	47.0	567

[a] On a 50:50 pigment-vehicle mixture, relative grading.

Lack of space makes it impracticable to publish all the reports as they were submitted, but the following brief summaries give some idea of the extent of the test program:

U. S. Bureau of Standards.—The Bureau report includes data obtained on the dry-film hiding power, using the method of Bruce.[1] Determinations were made by two observers to show the precision obtainable. The results, which are given in Table I, show an average deviation of 2 per cent with a maximum deviation of 5 per cent. These results were not corrected to equivalent brightnesses. The hiding powers of the wet paints were measured on the cryptometer, and an average deviation of 3 per cent obtained between the same two operators, and are shown in Table II. Tinting strength tests were made in accordance with the former A.S.T.M. Tentative Method D 282 - 28 T[2] and the results are recorded in Table III. This test was carried out by two operators and showed an average deviation of about 5 per cent, and a maximum deviation of 18 per cent.

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[1] H. D. Bruce, "A Photometric Method for Measuring the Hiding Power of Paints," *Technologic Paper, No. 306*, U. S. Bureau of Standards, January 16, 1926.

[2] *Loc. cit.*

The conclusions drawn from this report are that the results obtained for hiding power by the cryptometer and Bruce method are quite reproducible, but that the tinting strength shows considerably more variation and does not show differences of the same order of magnitude as those obtained on the hiding power tests for the six pigments.

E. I. duPont de Nemours and Co.—The report from this company contains a comparison between the former A.S.T.M. Tentative Method D 282 – 28 T and an ultramarine-blue tinting-strength test as used in the duPont laboratory.

In both cases the data from the two methods of testing were compared in two ways: first, using the basic carbonate white lead value as the comparison value (100), and then the lithopone value as the basis for comparison (100). Using the basic carbonate white lead value as the comparison basis, it was found that the results between the two tests differed widely, but by substituting the lithopone value for the basic carbonate white lead value as the basis for comparison the results of the two tests were more nearly in agreement, with the exception of white lead. The color of this pigment may be the cause for the difference in tinting strength values for white lead by the two methods when the lithopone value is used as the basis for comparison; likewise, it may be responsible for the general disagreement when white lead is used as the basis for comparison. The results are given in Table III.

TABLE II.—RESULTS OF HIDING POWER TESTS USING CRYPTOMETER.

	Bureau of Standards	duPont Laboratory X	New Jersey Zinc Co.	Gardner Laboratory	Pratt and Lambert	Johns Hopkins	Average
TESTS ON PAINTS AT ORIGINAL BRIGHTNESS, SQ. FT. PER GALLON							
Basic carbonate white lead	305	363	316	313	333	300	322
ZnO	246	292	233	250	242	232	249
Lithopone	289	353	282	311	277	292	301
Titanox	292	380	298	274	333	280	309
ZnS	411	468	430	436	404	430	430
TiO_2	592	613	632	581	555	560	589
TESTS ON PIGMENT, BASIS CALCULATED TO SQ. FT. PER POUND							
Basic carbonate white lead	15	17.6	15.2	...	15.9	...	...
ZnO	23	26.5	21.2	...	22.0	...	...
Lithopone	25	29.8	23.6	...	23.1	...	...
Titanox	24	30.9	24.1	...	26.9	...	...
ZnS	38	44.1	40.4	...	36.8	...	...
TiO_2	58	60.0	60.3	...	54.3	...	...

In conducting the cryptometer tests two different wedges were used and the results obtained check very closely. The average values obtained are given in Table II. Tests were also made on the cryptometer using a 50:50 mix of pigment and oil and the data tabulated in Table IV. Single-coat hiding power tests were made and indicate that the single-coat hiding method yields somewhat lower results than the cryptometer. These results are recorded in Table IV.

The conclusions drawn from this report are that the cryptometer gives quite consistent results and that the single coat hiding power test also gives consistent results, although slightly lower than the cryptometer. The tinting strength results by the two methods do not show good agreement because of the difficulty in making a brightness match in the presence of quite large color differences. It is also evident that the order of magnitude of the differences between the pigments as shown by the tinting strength test is much greater than the hiding power results show.

New Jersey Zinc Co. Research Laboratories.—The report of this laboratory contains a comparison between the former A.S.T.M. Tentative Method D 282 – 28 T and the preferred practice of the laboratory using ultramarine blue for tinting strength. According to the former A.S.T.M. method the range of tinting strength for the six samples is about 1 to 13, while in the case of preferred practice it is 1 to 6½. Tinting strength results are given in Table III. Cryptometer results are given on the paints (Table II) and on a 50:50 pigment vehicle mixture and results obtained by the spinning test are given for the paints and 50:50 mixtures (Table IV).

TABLE III.—RESULTS OF TINTING STRENGTH TESTS.

	Bureau of Standards	duPont Laboratories		New Jersey Zinc Co.	Gardner Laboratory, Modified Method	Pratt and Lambert, Modified Method	Ault and Wiborg	Average	Average, Modified Method
		Laboratory X	Laboratory Z, Lithopone Value as 100						
A.S.T.M. FORMER TENTATIVE METHOD D 282 – 28 T[a]									
Basic carbonate white lead...	100	100	100	100	100	100	...	100	100
ZnO..........	274	295	214	336	225	222	...	280	223
Lithopone..........	395	370	278	384	260	250	...	357	255
Titanox..........	516	525	373	538	410	400	...	488	405
ZnS..........	544	770	412	835	545	500	...	640	522
TiO_2..........	1053	1450	825	1336	1050	1000	...	1166	1025
PREFERRED LABORATORY PRACTICE									
Basic carbonate white lead...	....	100	100	100	....	100	100	100	....
ZnO..........	....	150	145	137	....	172	100	140	....
Lithopone..........	....	210	204	185	....	232	150	196	....
Titanox..........	....	284	277	273	....	291	180	261	....
ZnS..........	....	374	380	428	....	435	300	383	....
TiO_2..........	....	750	838	648	....	769	600	721	....

[a] The former Tentative Method of Test for Mass Color and Tinting Strength of Pigments (D 282 – 28 T), since discontinued, see *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 885 (1928).

The conclusions drawn from this report are that the former A.S.T.M. tentative method does not properly evaluate the pigments for tinting strength, that the tinting strength has no bearing on hiding power and that it is possible to measure hiding power with the cryptometer and to check those results very consistently with the spinning film method.

Henry A. Gardner Laboratory.—The report of this laboratory gives a tabulation of tinting strength results as obtained by a modification of the former A.S.T.M. tentative standard method D 282 – 28 T and correlation of the results of three operators using the cryptometer on the pigment-oil mixtures. They have also reduced the paints to equal consistencies and measured the hiding power. The laboratory has prepared a very extensive report of its work and findings in an article by Gardner, Sward and Levy, "Hiding Power and Tinting Strength of Pigments and Paints."[1]

The results of the tinting-strength tests are tabulated in Table III, and the cryptometer values in Table II.

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[1] *Circular 362*, Scientific Section, American Paint and Varnish Manufacturers Association.

Pratt and Lambert.—The Pratt and Lambert report contains hiding power results on the paints using the cryptometer and a brush-out method. Owing to the poor working qualities of the paints submitted the actual brush-out test must be considered as being not satisfactory. The high pigment content and the low spreading rate tend to give low figures for hiding power. There are two exceptions to this where slightly higher hiding power is recorded by the brush-out method. Cryptometer values are recorded in Table II and the brush-out values in Table I.

Tinting strength was determined by two methods, the former A.S.T.M. Tentative Method D 282 – 28 T and the preferred practice of Pratt and Lambert. These results are shown in Table III, and indicate that the former A.S.T.M. method gives too great a span and that the Pratt and Lambert preferred practice more nearly approaches the true tinting strength of the pigments.

Ault and Wiborg.—The Ault and Wiborg report contains results obtained by a tinting strength test in use in their laboratory as well as an opacity test which they have developed. Tinting strength values are given in Table III and opacity results in Table I. The tinting strength tests are in fair agreement with other tests of preferred practice, and the opacity test shows, in general, good agreement with hiding power results.

TABLE IV.—RESULTS OF HIDING POWER TESTS USING SPINNING TEST AND CRYPTOMETER.

	Tests Made on Paints (Wet), Results in sq. ft. per gallon			Tests Made on Pigments (Measured Wet), Results in sq. ft. per pound				
					New Jersey Zinc Co.			Spinning Results Calculated from Paint to Pigment Basis C. O.[a]
	duPont Laboratory, Single Coat	New Jersey Zinc Co., Spinning	Johns Hopkins, Black and White Cryptometer	duPont Laboratory, Cryptometer 50:50 Mix	C. O.[a] Spinning 50:50 Mix	Cryptometer Hiding Power on 50:50 Mix		
						As Is	At 80 per cent	
Basic carbonate white lead	332	321	290	19.8	19.2	17.3	19.5	15.4
ZnO	254	238	219	26.9	19.9	21.7	31.4	21.5
Lithopone	365	300	270	30.0	22.3	23.6	39.7	25.0
Titanox	380	310	273	31.7	19.7	21.0	52.5	25.0
ZnS	450	434	410	44.1	29.8	36.4	90.0	40.8
TiO_2	536	722	563	60.0	40.3	50.0	155.0	69.0

[a] Contrast-obliterating.

Johns Hopkins University.—The report of the University Department of Physics tabulates results on the regular cryptometer and on the black and white cryptometer. The differences noted between these two tests are small and apparently of no significance. The results are shown in Tables II and IV.

In view of the discrepancies noted in the case of tinting strength the program of the subcommittee is being so outlined that a tinting strength test will be developed if it is at all possible. All the methods of preferred practice will be written up in some detail and submitted to members of the subcommittee and the test which gives the best reproducibility will be adopted for tinting strength determination.

Future work will also be done on hiding power in an effort to correlate the wet hiding power results with dry hiding power results.

REPORT OF SUBCOMMITTEE XXV ON CELLULOSE ESTER COATINGS

Subcommittee XXV has been very active during the past year, having held two meetings, the first in Washington, October 14, 1929, and the second at Atlanta, Ga., April 8, 1930. Various sections of the subcommittee have also been active. As a result of this activity the subcommittee has developed a number of new specifications and is recommending that several of the tentative specifications under its jurisdiction be revised as given in detail below.

The Section on Resins is engaged in cooperative work looking toward the application of selected tests to specific resins, both natural and artificial. It is expected that sufficient progress will be made along this line so that proposed methods of test may possibly be submitted to Committee D-1 at the June meeting.

In regard to the work of the Section on Finished Lacquers, considerable discussion has taken place concerning the various methods of test. Subcommitee XXV realizes that the status of such tests as abrasion, hardness, adhesion, color, stress-strain measurements and the like is such as to preclude even the formulation of proposed tentative test procedures. These tests, however, are being actively investigated by a number of the laboratories represented by the personnel of the section and it is hoped that during the next year a portion of these may be submitted to Committee D-1.

The subcommittee recommends for publication as tentative, as appended hereto,[1] Proposed Tentative Specifications for Amyl Alcohol (Synthetic), for Amyl Acetate (Synthetic), for Butyl Propionate (90 to 93 per cent Grade), and for Ethyl Lactate (Synthetic).

Tentative Specifications for Soluble Nitrocellulose (*D 301 - 29 T*).[2]—The subcommittee recommends that these specifications be revised as follows and continued as tentative:

Section 8.—In the first line of the table, change the words "basic rosaniline" to read "pararosaniline."

Change the note following the table to read as follows, by the addition of the italicized words and the omission of those in brackets:

> The [rosaniline] *pararosaniline* acetate used in the foregoing formula is made by adding an excess of glacial acetic acid to 0.2500 g. of [basic rosaniline] *pararosaniline* and heating in a porcelain casserole over a steam bath until the

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[1] See pp. 1078 to 1081.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 639 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 292.

> excess acid is removed. The other ingredients are then added and volume made up to a total of 100 cc. with 95-per-cent ethyl alcohol. *The crystal violet mentioned in the formula may be replaced by Methyl Violet N.E. (E. I. duPont de Nemours and Co.) or Methyl Violet 2 B (National Aniline and Chemical Co.).*

In the second paragraph change the fourth sentence to read as follows, by the addition of the italicized words and the omission of those in brackets:

> The S and S No. 597 filter paper [gives excellent] *has been found to be the only paper giving consistent* results.

Section 9.—Change the first paragraph to read as follows by the addition of the italicized figures and the omission of the word in brackets:

> 9. Stability shall be determined by the [German] *134.5° C.* stability test, as follows.

In the first sentence of the third paragraph interchange the words xylol and toluol.

Section 11.—Change to read as follows, by the addition of the italicized words and figures and the omission of those in brackets:

> 11. (a) Cylinder.—A glass cylinder [1 in.] *1.0 ± 0.02 in (25.4 ± 0.5 mm.)* in inside diameter 14 in. in height and with marks *10.0 ± 0.10 in. (254.00 ± 0.25 mm.)* on the side at points *about* 2 and 12 in. from the top.
>
> (b) Steel Ball.—A steel ball [$\frac{5}{16}$ in. (0.793 mm.)] *0.3120 to 0.3130 in. (0.794 ± 0.001 cm.)* in diameter and weighing [2.046 to 2.054 g.] *2.035 ± 0.010 g.*

Section 12.—After the second sentence in the second paragraph add a sentence reading as follows:

> The solution of the nitrocellulose will be completed somewhat more quickly if the alcohol and toluol be added first and the mixture be then allowed to stand 5 or 10 minutes before the ethyl acetate is added.

In the fourth sentence of the second paragraph change the temperature "25° C. ± 0.5° C." to read "25.0° C. ± 0.1° C."

Change the fifth sentence of the second paragraph from its present form: namely,

> Then release the steel ball at the center of the top surface of the solution and allow it to fall through the solution.

to read as follows:

> Place the cylinder in a vertical position and release the steel ball at the center of the upper surface of the solution and allow it to fall through the solution.

Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (*D 268 – 29 T*)[1].—The subcommittee recommends that these specifications be revised as follows and continued as tentative:

Section 3.—Change from its present form: namely,

3. The specific gravity determination shall be made at 20° C. by any convenient method that is accurate to the third decimal point.

to read as follows:

3. The specific gravity shall be determined by any convenient method that is accurate to the third decimal point, the temperature of both sample and water being 20° C.

Section 4.—Change from its present form: namely,

4. The sample and the standard mutually agreed upon by the buyer and seller shall be compared in 50-cc. Nessler tubes against a white background. For a solvent to be rated water-white, the visible color shall not be darker than a solution of 0.0030 g. of potassium bichromate in one liter of water.

to read as follows:

4. The sample and the standard mutually agreed upon by the buyer and seller shall be compared in 100-cc. Nessler tubes having colorless bottoms and the sides of which are covered with opaque paper for the purpose of eliminating side light.[a] The tubes should be filled to a height of approximately 24.5 cm., and shall be viewed from a point directly above the tube, using a white background beneath the bottom of the tube. For a solvent to be rated water-white, the visible color shall not be darker than a solution of 0.0030 g. of potassium bichromate in one liter of water when tested in the above manner.

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[a] Tubes conforming to these requirements may be obtained from the New Jersey Laboratory Supply Co., Newark, N. J., their Catalog No. 22565.

Section 5.—Change from its present form: namely,

5.—The distillation test shall be conducted in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials, except that all observations of volumes of distillate shall be read at the temperature specified for the individual solvent or diluent under test.

to read as follows:

5. The distillation test shall be conducted in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials, with the following exceptions:

(*a*) The temperature of the end point of the distillation, which shall be termed the "dry point," is the temperature observed on the distillation ther-

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 672 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 330.

> mometer when the last drop of liquid leaves the bottom of the distillation flask. The thermometer used shall conform to the requirements of either the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) or the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −5 to +300° C., +20 to +580° F. (A.S.T.M. Designation: D 183) of the American Society for Testing Materials, as specified.
>
> (*b*) Observation of volumes of distillate shall be made at the temperature specified for the individual solvent or diluent under test.

Section 8.—Change the last sentence from its present form: namely,

> They shall then be attached to a piece of wood with thumb tacks and at suitable intervals examined for difference in odor.

to read as follows:

> The filter papers shall be allowed to dry in air at room temperature and shall be examined at suitable intervals for difference in odor.

Section 9.—After the first sentence add the following sentence:

> Both sample and gasoline shall be at a temperature of 20° C. when used.

Section 10.—Change the last sentence to read as follows by the addition of the italicized words:

> The weight of the sample shall be determined from the specific gravity and the acidity reported *as percentage by weight of the appropriate acid, or* as milligrams of KOH per gram of sample.

Section 12.—Reletter the present section as Paragraph (*a*) and add the following optional method for ester value as Paragraph (*b*):

> (*b*) One to two grams of the sample shall be weighed in an ampoule by first weighing the empty ampoule, warming and filling, and then sealing off and reweighing (Note). The ampoule shall be placed in a pressure bottle of approximately 325-cc. capacity (the spring top magnesium-citrate bottle is satisfactory) which contains one and one-half times the theoretical quantity of 0.5*N* KOH required for complete saponification. The ampoule may be broken with a glass rod, subsequently washing the liquid adhering to the rod back into the bottle. After thorough agitation the bottle and contents shall be heated on a steam bath for 1 to 4 hours, depending upon the ester being tested. After the proper heating, the bottle shall be allowed to cool, then opened and the under side of the stopper and the sides of the neck washed down with distilled water. Three drops of the phenolphthalein solution shall be added to the contents of the flask as an indicator. The contents of the flask shall be titrated therein with 0.5*N* HCl. Two blanks with alcoholic KOH shall be run along with the sample. These blanks should check, on titration, to the first decimal point. The result should be reported as percentage of ester by weight, making allowance in the calculations for acidity or alkalinity as determined in Sections 10 and 11.

NOTE.—An optional method of weighing the sample is in a small weighing bottle, removing the stopper, by means of a glass rod after introduction into the pressure bottle, or by agitating the contents of the pressure bottle.

Section 13.—Change the last two sentences to read as follows by the addition of the italicized words and the omission of those in brackets:

> The liquid shall be poured off and the copper examined for *tarnishing or* blackening. [A slight tarnish shall be disregarded, but any marked blackening shall be cause for rejection.]

Tentative Specifications for Ethyl Acetate (85 to 88 per cent Grade) (D 302 - 29 T).[1]—The subcommittee recommends that these specifications be revised as follows and continued as tentative:

Section 1.—In the table change the requirements for residue and water to read as follows by the addition of the italicized words and figures and the omission of the word in brackets:

Residue	[none] *not more than 0.005 g.*
Water	miscible without turbidity with ten volumes of 60° Baumé gasoline *at 20° C.*

In the table add the following footnote reference to "distillation range":

> The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.

Tentative Specifications for Butyl Acetate (85 to 88 per cent Grade) (D 303 - 29 T).[2]—The subcommittee recommends that these specifications be revised as follows and continued as tentative:

Title.—Change the title to read as follows by the addition of the italicized word and figures and the omission of the figures in brackets:

> Tentative Specifications for *Normal* Butyl Acetate ([85 to 88] *88 to 92* per cent Grade).

Section 1.—In the table change the requirements for specific gravity, distillation range, residue, water and ester value to read as follows, by the addition of the italicized words and figures and the omission of those in brackets:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 649 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 302.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 650 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 303.

Specific gravity, 20°/20° C.	[0.870 to 0.875] *0.872 to 0.878*
Distillation range:	
[Below 125° C.] *Above 127° C.*	[not less than 70 per cent] *not more than 30 per cent*
Residue	[none] *not more than 0.005 g.*
Water	miscible without turbidity in all proportions with 60° Baumé gasoline *at 20° C.*
Ester value	[85 to 88] *88 to 92* per cent by weight

In the table add the following footnote reference to "distillation range":

> The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.

Tentative Specifications for Butanol (*Normal Butyl Alcohol*) (*D 304–29 T*).[1]—The subcommittee recommends that these specifications be revised as follows and continued as tentative:

In the table change the requirements for purity, distillation range, residue and water to read as follows, by the addition of the italicized words and figures and the omission of those in brackets:

Purity	*to contain not less than* [98 to 100] *98* per cent of normal butyl alcohol
Distillation range:	
[Between 100 and 118° C.] *Below 100° C*	[100 per cent] *none*
Below 105° C	not more than 2 per cent
Below 115° C	not more than 10 per cent
Above 118° C	*none*
Residue	[none] *not more than 0.005 g.*
Water	no cloud when one volume of Butanol is mixed with 19 volumes of 60° Baumé gasoline *at 20° C.*

In the table add the following footnote reference to "distillation range":

> The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immerison Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.

Respectfully submitted on behalf of the subcommittee,

I. C. MATTHEWS,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 651 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 304.

REPORT OF COMMITTEE D-2
ON
PETROLEUM PRODUCTS AND LUBRICANTS

Committee D-2 on Petroleum Products and Lubricants has held three regular meetings during the past year (in June at Atlantic City, in January at Baltimore, and in March at Detroit) and also an informal meeting in December at Chicago, at the time of the annual meeting of the American Petroleum Institute.

The By-laws of the committee have been revised to provide for "Technical Committees" in addition to "Subcommittees." The principal function of subcommittees shall be "to study methods of testing and to recommend revision of present tentative or standard methods and new tentative or standard methods as need arises," while that of technical committees shall be "to study the relation between test data and service performance of materials and to prepare and recommend material specifications."

Three technical committees have been organized as follows:

Technical Committee A on Gasoline (H. L. Horning, chairman, C. B. Veal, vice-chairman, and T. G. Delbridge, secretary);

Technical Committee B on Motor Oils (H. C. Mougey, chairman, and J. G. Detwiler, secretary); and

Technical Committee C on Fuel Oils (Including Diesel Fuels) (Lee Schneitter, chairman, Commander C. C. Ross, first vice-chairman, L. H. Morrison, second vice-chairman, and A. E. Flowers, secretary).

Technical Committee C on Fuel Oils (Including Diesel Fuels) also functions as a Sectional Committee under the procedure of the American Standards Association with the Society as sponsor. Two important sections have been created: the Section on Domestic and Industrial Fuel Oil (C. C. Ross, chairman, and H. F. Tapp, secretary), and the Section on Diesel Fuel (L. H. Morrison, chairman, and W. H. Butler, secretary). Former Subcommittee XXX on Fuel Oils, which has been made a standing committee on Fuel Oils of the Commercial Standards Unit of the Department of Commerce, served as a nucleus of the Section on Domestic and Industrial Fuel Oil and the Diesel Fuel Research Committee of the American Society of Mechanical Engineers served as a nucleus of the Section on Diesel Fuels.

Subcommittees XVII on Gasoline, XXIX on Motor Oils, and XXX on Fuel Oils have ceased to exist with the organization of these new technical committees.

Acting as the Sectional Committee on Methods of Testing Petroleum Products and Lubricants functioning under the American Standards Association, the following two methods of test were submitted to the A.S.A. for approval. The methods have since been approved by the A.S.A. with the A.S.A. Numbers indicated below:

(1) The A.S.T.M. Standard Method of Test for Saponification Number (D 94 - 28) (A.S.A. No. Z11t - 1930); approved as an American Standard, and

(2) The A.S.T.M. Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline (D 130 - 27 T) (A.S.A. No. Z11u - 1930), approved as an American Tentative Standard.

The voting membership of Committee D-2 now consists of 42 producer, 34 consumer, and 13 general interest members.

ACTIVITIES OF SUBCOMMITTEES

Appended hereto are reports of the following subcommittees:

Subcommittee V on Viscosity
Subcommittee XXV on Crankcase Dilution
Subcommittee XXVIII on Autogenous Ignition of Petroleum Products

In addition to the subcommittee reports appended, the activities of other subcommittees are presented as follows:

Subcommittee IV on Grease (A. R. Lange, chairman).—This subcommittee has had under consideration during the present year the question of developing a suitable method for the determination of the melting point of greases. Following correspondence between the members on this subject and after discussion in Chicago at the December meeting and in Baltimore at the January meeting, it was agreed that the term "melting point" as applied to grease is a misnomer and that the characteristic of greatest importance is the pressure-flow relationship of greases at various temperatures approaching what is commonly known as the melting point. Experimental work along this line will be initiated during the present year.

Comparative tests will also be carried on by the subcommittee using the A.S.T.M. penetrometer on very soft and very hard greases. For the former an aluminum frame and cone with a total weight of 50 g. will be tried. On the latter, the regular asphalt penetration method with regular equipment will be used.

The subcommittee recommends that the Tentative Method of Test for Penetration of Greases and Petrolatum (D 217 - 27 T) remain tentative for another year.

Subcommittee XI on Turbine Oil (Harold Farmer, chairman).—The subcommittee reports that arrangements have been completed for collecting service performance data on several turbine oils in use in large steam turbines.

These service data are necessary in connection with the investigation of laboratory tests (oxidation tests, life tests, service tests, etc.).

The subcommittee will welcome information concerning any laboratory tests employed in the selection of satisfactory turbine oils, with a view to incorporating such tests in this investigation.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

PROPOSED NEW TENTATIVE STANDARDS

The committee is presenting for approval for publication as tentative the following methods:

Proposed Tentative Method of Test for Vapor Pressure of Natural Gasoline (Reid Method), submitted by Subcommittee XXII on Natural Gas Gasoline (G. G. Oberfell, chairman), as appended hereto.[1]

Proposed Tentative Method of Test for Dilution of Crankcase Oils, submitted by Subcommittee XXV on Crankcase Dilution as appended hereto.[2]

PROPOSED REVISION OF STANDARD METHODS

The committee recommends the following revisions of eight standard methods to become effective immediately. It accordingly asks for the necessary nine-tenths vote.

Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (D 86 - 27).[3]—The following minor changes are recommended by Subcommittee VIII on Distillation (E. W. Dean, chairman):

Section 9.—Change the seventh sentence to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> The volume of distillate collected in the cylinder shall be observed and recorded, to the nearest 0.5 cc., when the mercury of the thermometer reaches

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[1] See p. 1139.—ED.

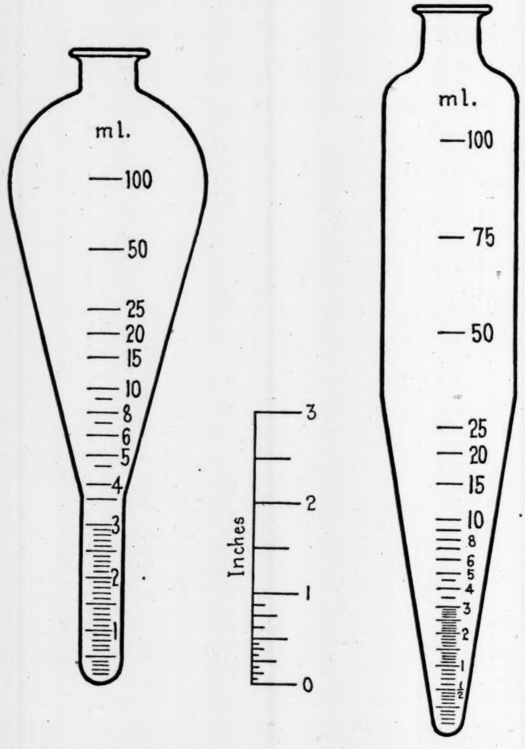
[2] See p. 1112.—ED.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

each point that is [an even] *a* multiple of [25° C.] *10° C.* or the Fahrenheit equivalent of this point (*30° C.*, *40° C.*, 50° C., *60° C.*, [75° C., 100° C., 125° C.] etc., or *86° F.*, *104° F.*, 122° F., *140° F.*, [167° F., 212° F., 257° F.,] etc.).

Change the second and third paragraphs from their present form: namely,

When the liquid residue in the distillation flask is approximately 5 cc. the heat may be increased because of the presence of heavy ends which have relatively high boiling points. However, no further increase of heat shall be applied after this adjustment. The 4 to 5-cc. rate can rarely be maintained from this point to the end of the distillation, but in no case shall the period between the point when approximately 5 cc. of liquid remains in the flask and the end point be more than 5 minutes.



(*a*) Pear-Shaped Tube. (*b*) Cone-Shaped Tube.

FIG. 1.—A.S.T.M. Centrifuge Tubes.

The heating shall be continued until the mercury reaches a maximum and starts to fall consistently. The highest temperature observed on the distillation thermometer shall be recorded as the *maximum temperature* or end point. Usually this point will be reached after the bottom of the flask has become dry.

to read as follows:

No adjustment of the heat shall be made after the liquid residue in the flask is approximately 5 ml. unless the time required to bring over the last 5 ml. of distillate and reach the end point exceeds 5 minutes. The end point is the maximum temperature observed on the distillation thermometer and is usually reached after the bottom of the flask has become dry. If the bottom of the flask is not dry the operator shall record this fact.

In case the time required to bring over the last 5 ml. of distillate and reach the end point exceeds 5 minutes the test shall be repeated and the heat shall be adjusted when the liquid residue reaches 5 ml. This adjustment may be either an increase or a decrease but must accomplish the purpose of bringing the period required to vaporize the last 5 ml. of distillate and reach the end point within the limits of 3 and 5 minutes.

Section 10.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

With proper care and attention to detail, duplicate results obtained for initial boiling point and [maximum temperature] *end point*, respectively, should not differ from each other by more than 6° F. (3.3° C.).

Standard Method of Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96 – 28).[1]—The following changes are recommended by Subcommittee XIV on Water and Sediment (H. R. Gundlach, chairman) to provide a more accurate description of the centrifuge tubes used in the method:

Figure 1.—Replace Fig. 1 by the accompanying Fig. 1(*a*) Pear-Shaped Tube and Fig. 1(*b*) Cone-Shaped Tube.

Section 4.—Change from its present form: namely,

4. The centrifuge tubes, A.S.T.M. type, shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 cc. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube. The value of the divisions for each range shall not be greater than shown in the following tabulation:

RANGE	SCALE DIVISIONS	LIMIT OF ERROR	NUMBERED
0 – 3 cc.	0.1 cc.	0.05 cc.	1, 2, 3 cc
3 – 5 "	0.5 "	0.2 "	4, 5 "
5 – 10 "	1.0 "	0.5 "	6, 8, 10 "
10 – 25 "	5.0 "	1.0 "	15, 20, 25 "
50 – 100 "	50.0 "	1.0 "	50, 100 "

The shape is optional provided it does not conflict with the other requirements. Satisfactory types are shown in Fig. 1.

to read as follows:

4. The centrifuge tubes, A.S.T.M. types shown in Fig. 1, shall be made of suitable glass and thoroughly annealed. The total capacity shall be about

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 152.

125 ml. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube. The length and outside diameter are optional provided they do not conflict with the other requirements. The value of the divisions for each range with limits of error are given in the following tabulations for the A.S.T.M. Pear-Shaped Tube and A.S.T.M. Cone-Shaped Tube.

A.S.T.M. PEAR-SHAPED TUBE.

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 3 ml.	0.1 ml.	0.05 ml.	1, 2, 3 ml.
3 to 5 "	0.5 "	0.2 "	4, 5 "
5 to 10 "	1.0 "	0.5 "	6, 8, 10 "
10 to 25 "	5.0 "	1.0 "	15, 20, 25 "
25 to 50 "	25.0 "	1.0 "	50 "
50 to 100 "	50.0 "	1.0 "	100 "

A.S.T.M. CONE-SHAPED TUBE.

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 0.1 ml.	0.05 ml.	0.02 ml.	....
0.1 to 0.3 "	0.05 "	0.03 "	....
0.3 to 0.5 "	0.05 "	0.05 "	½ ml.
0.5 to 1.0 "	0.1 "	0.05 "	1 "
1 to 3 "	0.1 "	0.1 "	2, 3 "
3 to 5 "	0.5 "	0.2 "	4, 5 "
5 to 10 "	1.0 "	0.5 "	6, 8, 10 "
10 to 25 "	5.0 "	1.0 "	15, 20, 25 "
25 to 100 "	25.0 "	1.0 "	50, 75, 100 "

Standard Method of Test for Cloud and Pour Points of Petroleum Products (D 97 - 28).[1]—The following clarifying changes are recommended by Subcommittee XVI on Cloud and Pour Points (J. B. Rather, chairman):

Section 10.—Add the following sentence at the end of the sixth paragraph:

> If the oil does not show a cloud when it has been cooled to 15° F., the test jar shall be placed directly in a cooling bath of suitable temperature.

Section 11.—Replace the third sentence of the third paragraph which reads as follows:

> Oils with which the low cloud and pour test thermometer can be used from the beginning of the test shall be cooled to 60° F. in any convenient manner before the thermometer is placed in position.

with a new sentence to read as follows:

> Oils on which a very low pour point is expected shall be heated as above with the high cloud and pour test thermometer in position, cooled to 60° F. and the low cloud and pour test thermometer placed in position.

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 133.

Insert the following sentence after the second sentence of the seventh paragraph:

> If the oil has not ceased to flow when its temperature has reached 15° F., the cold test jar shall be placed directly in a cooling bath of suitable temperature.

Standard Method of Test for Burning Quality of Kerosine Oils (D 187 - 27).[1]—The following changes in the tolerances of the burner and the chimney are recommended by Subcommittee XIX on Illuminating Oils (J. B. Rather, chairman) to make it possible to utilize apparatus now obtainable without affecting the results of the tests:

Section 3.—Change to read as follows, by the addition of the italicized words and figures and the omission of those in brackets:

> 3. Miller No. 2 Sun Hinge Burner (see Fig. 2) or any other burner conforming to the following requirements:

	Inches	Centimeters	Tolerances, cm.
Upper Part of Burner:			
Thickness of metal [24 B. & S. gage]	*No. 26 ± 1 B. & S. Gage*		
Height of cone from base of cone (outside)	1.20	3.05	0.05
Inside diameter of cone at base *measured at base in constriction*	[1.81] *1.77*	[4.60] *4.50*	0.02
Inside diameter of cone at base of flame spreader:			
(1) parallel to slot	[1.43] *1.42*	[3.64] *3.60*	0.02
(2) perpendicular to slot	[1.43] *1.42*	[3.62] *3.60*	0.02
Height of cone from base to a point 1 cm.			
(1) right of center	1.15	2.92	0.06
(2) left of center	1.15	2.92	0.06
Over-all diameter of flame spreader at base	[2.76] *2.79*	[7.01] *7.08*	[0.01] *0.05*
Height of collar at flame spreader base	0.31	0.79	0.07
Diameter of scallops	0.21	0.54	....
Depth of scallops	0.08	0.20	....
Center of screw to bottom of collar (outside)	0.29	0.73	....
Holes at base of spreader, 28 in number:			
(1) diameter	0.09	0.24	0.01
(2) spacing, edge to edge	0.14	0.35	[0.02] *0.03*
Space at back of flame spreader collar (without holes)	0.83	2.10	....
Space at front of flame spreader collar (without holes)	0.61	1.55	....
Width of flame spreader slot at top:			
(1) center	0.39	1.00	0.03
(2) 1 cm. to left of center	0.39	1.00	0.03
(3) 1 cm. to right of center	0.39	1.00	0.03
Width of wick holder (outside)	0.96	2.44	[0.01] *0.02*
Depth of wick holder (outside)	0.17	0.44	[0.01] *0.02*
Length of wick holder	1.75	4.45	0.02

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 364.

	INCHES	CENTIMETERS	TOLERANCES, CM.
UPPER PART OF BURNER (Continued):			
Width of air vent (outside)	0.34	0.87	....
Depth of air vent (outside)	0.08	0.20	....
Length of air vent	1.67	4.25	[0.01] *0.02*
Top of wick holder to base of flame spreader slot	0.03	0.08	0.06
Base of flame spreader slot (inside) to edge of wick holder (outside):	[0.23]	[0.59]	[0.07]
(*1*) *right*	*0.23*	*0.59*	*0.07*
(*2*) *left*	*0.23*	*0.59*	*0.07*
Edge of flame spreader slot (top center) to top center edge of wick holder	[0.11] *0.57*	[0.29] *1.44*	[0.05] *0.03*
Wick holder (to run parallel to flame spreader slot).			
LOWER PART OF BURNER:			
Diameter at widest point (parallel to slot)	2.22	5.64	[0.02] *0.03*
Diameter at first constriction	2.18	5.53	[0.02] *0.03*
Diameter at second constriction	1.96	4.97	[0.02] *0.03*
Diameter at third constriction	1.42	3.60	[0.02] *0.03*
[Diameter at fourth constriction	1.22	3.10	0.02]
Bottom (threaded to fit standard brass Saybolt test lamp)			
[Diameter at bottom	1.19	3.02	0.02]
Ventilating openings, 12 in number, width:			
(1) center	0.29	0.73	[0.01] *0.03*
(2) top and bottom	0.21	0.54	[0.01] *0.03*
Ventilating openings, height:			
(1) center	0.24	0.61	[0.01] *0.03*
(2) sides	[0.32] *0.28*	[0.81] *0.72*	[0.01] *0.03*
Top of wick holder to top of holder support.	1.01	2.57	[0.03] *0.05*
Top of lower [half] *part* of burner to [outside holder support] *fourth constriction*	[0.62] *0.63*	[1.57] *1.60*	[0.02] *0.04*
SCREEN:			
Diameter of screen	[2.12] *1.92*	[5.38] *4.88*	0.02
[Length of slot in screen	1.01	2.56	0.05]
[Width of slot (1) narrowest point	0.20	0.52	0.02]
[Width of slot (2) widest point	0.30	0.75	0.02]
Diameter of holes in screen	0.05	0.12	0.03
Number of holes in screen per sq. cm., 45, with a tolerance of 7			
Height of screen from base to top (over-all).	0.11	0.29	[0.01] *0.03*
[Diameter of screen at top	1.16	2.94	0.02]
[Diameter of screen at rim	0.10	0.26	0.01]

Screen to fit snugly around wick holder and air vent.

NOTE.—The burner shall be used as received from the manufacturer provided it meets the above specifications and is free from gross imperfections of manufacture. It shall be clean and in good condition at the start of the test, but emery paper shall not be used in cleaning nor imperfections removed by means of a file or otherwise.

Section 4.—Change to read as follows, by the addition of the italicized figures and the omission of those in brackets:

4. Macbeth-Evans No. 514 Pearl Top Chimney. (See Fig. 1.)—The chimney shall conform to the following requirements, all figures being outside measurements:

	INCHES	CENTIMETERS	TOLERANCES, CM.
Total height	[8.06] *8.28*	[20.48] *21.00*	0.50
Diameter of constriction:			
(1) upper	1.77	4.50	[0.08] *0.10*
(2) lower	2.27	5.77	[0.07] *0.10*
Diameter at widest point	3.69	9.36	*0.20*
Diameter at top	2.83	7.20	[0.09] *0.15*
Diameter at bottom	2.60	6.61	[0.06] *0.10*
Distance from bottom to narrowest point	[7.03] *7.28*	[17.86] *18.46*	0.55
Distance from bottom to widest point	2.47	6.27	0.55
Distance from bottom to constriction near bottom	0.30	0.77	0.19
Thickness of glass at constriction:			
(1) top	0.07	0.19	0.05
(2) bottom	[0.05] *0.06*	[0.12] *0.15*	[0.03] *0.05*

Standard Method of Test for Burning Quality of Long-Time Burning Oil for Railway Use (D 219 - 27).[1]—The following changes are recommended by Subcommittee XIX on Illuminating Oils (J. B. Rather, chairman):

Section 4.—Flame Spreader.—Change from its present form: namely,

> *Flame Spreader.*—Cylindrical, $\frac{5}{16}$ in. in height and $\frac{1}{2}$ in. in inside diameter, soldered to the top of wick tube. Two V-shaped slots, placed opposite to each other, with top of V $\frac{1}{4}$ in. wide and bottom ending just above top of wick tube.

to read as follows:

> *Flame Spreader.*—The flame spreader shall be cylindrical with two V-shaped slots placed opposite each other, and with the bottom of the slots ending just above the wick tube.

Wick Tube.—Omit this paragraph, which reads as follows:

> *Wick Tube.*—$1\frac{5}{16}$ in. in length, $\frac{1}{4}$ in. in inside diameter, and extending $\frac{5}{8}$ in. above top of burner base.

Chimney Support Ring.—Change this paragraph from its present form: namely,

> *Chimney Support Ring.*—$1\frac{1}{4}$ in. in inside diameter, $\frac{7}{16}$ in. below top of flame spreader, equipped with 4 springs to hold chimney in place.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 370.

to read as follows:

Chimney Support Ring.—The chimney support ring shall be equipped with four springs to hold the chimney in place.

Air Vents.—Omit this paragraph, which reads as follows:

Four $\frac{1}{16}$ in. holes placed symmetrically in flame spreader just above the top of the wick tube; four rectangular openings, $\frac{7}{16}$ in. high, by $\frac{9}{16}$ in. wide, placed below the chimney support ring and between the chimney springs.

Add a new table of requirements reading as follows:

BURNER DIMENSIONS	INCHES	CENTIMETERS	TOLERANCES, CM.
Height of flame spreader (outside)	0.31	0.79	0.08
Diameter of flame spreader (inside)	0.50	1.27	0.08
Width of top of V-shaped slots in flame spreader	0.31	0.79	0.08
Length of wick tube	1.31	3.33	0.08
Diameter of wick tube	0.25	0.63	0.04
Height of wick tube from top of burner base	0.62	1.59	0.08
Diameter of chimney support ring (inside)	1.25	3.18	0.08
Top of chimney support ring to top of flame spreader.	0.44	1.11	0.08
Diameter of air vents in flame spreader (placed symmetrically)	0.06	0.16	0.04
Rectangular openings, 4 in number:			
(1) Height	0.44	1.11	0.08
(2) Width	0.56	1.43	0.08

Section 5.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

5. The chimney shall be a No. 55-D Chimney,[a] or any other chimney *with straight glass wall beaded at top and bottom, and conforming to* [meeting] the following requirements: [Straight wall glass 2½ in. high and 1⅛ in. in inside diameter, with rim at top and bottom.]

	Inches	*Centimeters*	*Tolerances, cm.*
Height	*2.50*	*6.35*	*0.08*
Diameter (inside)	*1.12*	*2.86*	*0.08*

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[a] This term, "55-D Chimney," is fully descriptive with glass manufacturing companies as the ong-time burner chimney covered by these specifications.

Standard Method of Test for Burning Quality of Mineral Seal Oil (D 239 – 27).[1]—The following changes in the tolerances of the burner and the chimney are recommended by Subcommittee XIX on Illuminating Oils (J. B. Rather, chairman) to make it possible to utilize apparatus now obtainable without affecting the results of the tests:

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 374.

Section 4.—Revise the following portions of this section by the addition of the italicized words and figures and the omission of those in brackets:

UPPER PART OF BURNER:	INCHES	CENTIMETERS	TOLERANCES, CM.
Thickness of metal, [No. 24 B. & S. gage]...	*No. 22 ± 1 B. & S. gage*		
Height of cone from base of cone:			
(2) 1 cm. to right of center............	1.57	3.98	[0.03] *0.05*
Inside diameter of cone at base of flame spreader slot:			
(1) Parallel to slot....................	[1.49] *1.50*	[3.79] *3.81*	[0.01] *0.02*
(2) Perpendicular to slot..............	[1.52] *1.50*	[3.85] *3.81*	[0.01] *0.02*
LOWER PART OF BURNER:			
Wick holders:			
(3) Length...........................	2.54	6.44	[0.02] *0.03*

FOLLOWING MEASUREMENTS TAKEN WITH UPPER PART OF BURNER FITTED EVENLY AND TIGHTLY ON LOWER PART:

	INCHES	CENTIMETERS	TOLERANCES, CM.
Base of flame spreader slot (inside) to edge of wick holder (outside):	[0.13	0.34	0.04]
(1) Right............................	*0.13*	*0.34*	*0.04*
(2) Left.............................	*0.13*	*0.34*	*0.04*
Height of burner (over-all)...............	3.24	8.23	[0.03] *0.05*

Section 5.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

5. The chimney shall be a [Keystone No. 24] *Macbeth No. 16* Chimney or any other chimney [meeting] *conforming to* the following requirements:[a]

	INCHES	CENTIMETERS	TOLERANCES, CM.
Total height..........................	[9.94] *9.92*	[25.24] *25.20*	*0.40*
Diameter at top.......................	[1.60] *1.65*	[4.06] *4.19*	[0.02] *0.10*
Diameter at a point 1.75 in. (4.44 cm.) from top.........................	1.60	4.06	[0.02] *0.10*
Diameter at a point 5 in. from top.......	[2.60] *2.72*	[6.60] *6.90*	*0.30*
Diameter at widest point................	[3.58] *3.47*	[9.10] *8.80*	*0.30*
Diameter at the bottom.................	[2.55] *2.52*	[6.47] *6.40*	[0.03] *0.10*
Distance from bottom to widest point....	[2.69] *2.95*	[6.78] *7.50*	[0.11] *0.20*
Distance from bottom to constriction near bottom............................	[0.94] *1.18*	[2.38] *3.00*	*0.10*
Thickness of glass at top...............	0.06	0.14	[0.01] *0.02*
Thickness of glass at bottom............	[0.05] *0.06*	[0.12] *0.16*	0.03

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[a] All measurements are outside.

The use of the chimney specified in the 1927 Edition[1] *of this standard method is permissible.*

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[1] 1927 Book of A.S.T.M. Standards, **Part II**, p. 374.

Standard Method of Test for Distillation of Natural Gas Gasoline (*D 216 - 27*).[1]—The following changes are recommended by Subcommittee XXII on Natural Gas Gasoline (G. G. Oberfell, chairman):

Section 9 (*f*).—Change the second sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> The graduate shall be immersed [at least] up to the [100-cc. mark] *level of the outlet of the condenser tube* in a transparent bath maintained between the temperatures of 32 and 34° F. (0 and 1.1° C.).

Section 10.—Add the following sentence at the end of the first paragraph:

> In case a product is being tested to ascertain whether or not it conforms with a given specification, all necessary observations shall be made and recorded, whether or not they are included in the series ordinarily employed by the laboratory making the test.

New Section.—Insert the following paragraph on Accuracy as Section 11 and renumber the present Sections 11 and 12 accordingly:

> 11. *Accuracy.*—With proper care and attention to detail duplicate results obtained for end point should not differ from each other by more than 6° F. (3.3° C.). Differences in duplicate temperature readings for each prescribed percentage point should not exceed the amounts equivalent to 2 cc. of distillate at each point in question.

Section 11.—Correction for Barometric Pressure.—Renumber as Section 12 and add the following sentence at the end of the first paragraph:

> In case of dispute, however, no test shall be regarded as official when conducted under an absolute pressure lower than 735 mm. (28.94 in.) of mercury.

Standard Method of Test for Carbon Residue of Petroleum Products (*Conradson Carbon Residue*) (*D 189 - 28*).[2]—The following changes are recommended by Subcommittee XXIII on Carbon Residue (F. R. Baxter, chairman) to provide reasonable tolerances for the apparatus now in common use, or obtainable, and to limit the time taken for burning the vapors following the pre-ignition period:

Section 2.—Change Paragraphs (*a*), (*b*) and (*c*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> (*a*) Porcelain crucible, wide form, glazed throughout, or a silica crucible; [25 to 26-ml. (0.8-oz.)] *29 to 31-ml.* capacity, 46 *to 49* mm. ([1⅞] *1.81 to 1.93* in.) in [approximate] rim diameter.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 387.

[2] 1928 Supplement to Book of A.S.T.M. Standards, p. 129.

(*b*) Skidmore iron crucible flanged and ringed, [60 to 80] *65 to 82*-ml. [approximate] capacity, [55] *53 to 57* mm. ([2⅛] *2.07 to 2.20* in.) inside and [65] *60 to 67* mm. ([2⅝] *2.36 to 2.64* in.) outside diameter [at the top] *of flange*, 37 to 39 mm. ([about 1½ to 1⅝ in.] *1.46 to 1.54 in.*) in height supplied with a cover without delivery tubes and having the vertical opening closed. The horizontal opening *of about 6.5 mm.* (*0.26 in.*) shall be kept clean. *The outside diameter of the flat bottom shall be 30 to 32 mm.* (*1.18 to 1.26 in.*).

(*c*) Spun sheet-iron crucible, with cover; [about 200-ml. (7-oz.) capacity] [80] *78 to 82* mm. ([3⅛] *3.07 to 3.23* in.) in outside diameter at the top, 58 to 60 mm. (about [2⅜] *2.3* in.) in height, *and* approximately 0.8 mm. ([$\frac{1}{32}$] *0.03* in.) in thickness. [and weighing, without cover, 70 to 75 g. (about 2½ oz.).] Place at the bottom of this crucible, and level before each test, a layer of about 25 ml. of dry sand, or enough to bring the Skidmore crucible, with cover on, nearly to the top of the sheet-iron crucible.

Section 3.—At the end of the third paragraph add the following sentence:

The period of burning the vapors shall not be less than 12 nor more than 14 minutes.

ADVANCEMENT OF TENTATIVE REVISIONS OF STANDARD METHODS TO STANDARD

The committee recommends that the tentative revisions proposed last year[1] in the following methods be advanced to standard and incorporated in the standard methods:

Standard Method of Test for Viscosity of Petroleum Products and Lubricants (D 88 – 26).[2]

Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 – 27).[3]

Standard Method of Test for Water in Petroleum Products and Other Bituminous Materials (D 95 – 28).[4]

PROPOSED REVISIONS OF TENTATIVE STANDARDS

The committee recommends revisions of the following methods of test and that the methods as revised be continued as tentative:

Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 – 28 T).[5]—The following changes are recommended by Subcommittee II on Specific Gravity

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 869, 870 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 823, 824.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 427.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 378.

[4] 1928 Supplement to Book of A.S.T.M. Standards, p. 148.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 924 (1928); also 1929 Book of A.S.T.M Tentative Standards, p. 388.

(K. G. Mackenzie, chairman) as a result of suggestions received during the past year:

Section 1.—Change the first sentence to read as follows by the addition of the italicized word and the omission of the word in brackets:

> 1. This method covers the determination of the specific gravity [or] *and* the A.P.I. gravity of crude petroleum and petroleum products normally handled as liquids.

Section 3.—Add the following sentence after the second sentence of the first paragraph:

> The gravity scale shall be printed in black ink.

Add the following sentence at the end of the first paragraph:

> There shall be a mark on the stem of the hydrometer corresponding to a fixed mark on the paper scale, to provide a check against possible displacement of the scale.

In the second sentence of the second paragraph, change the lower limit of the softening point of the cement from "195° F." to read "215° F."

Section 4.—Where both Centigrade and Fahrenheit values are given in Paragraph (*a*), change the order so that the Fahrenheit values will precede the Centigrade values.

Change the second sentence of Paragraph (*b*) to read as follows by the addition of the italicized words:

> The paper *temperature* scale shall be graduated in 2° F. divisions accurate to ± 1° F. (Note) and, *when located in the stem of the hydrometer,* shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale.

Section 5.—Change the first sentence to read as follows by the addition of the italicized words and the omission of those in brackets:

> 5. Hydrometer Cylinder.—The hydrometer cylinder in which the sample for the gravity test is confined [shall] *may* be made of *metal or* clear glass and shall be cylindrical in shape.

Section 7.—Add a Note at the end of the second paragraph to read as follows:

> NOTE.—In the routine testing of opaque crude petroleum with the usual type of hydrometer with a 12-deg. range, it is customary and permissible to correct the reading taken as prescribed above for non-transparent samples by an arbitrary deduction of 0.1° A.P.I. from the observed gravity reading.

Tentative Method of Test for Sulfur in Motor Fuels, Naphthas and Illuminating Oils (Lamp Method) (D 90 – 29 T).[1]— The following changes are recommended by Subcommittee VII on Sulfur Determination and Differentiation (T. A. Boyd, chairman):

Figure 1.—Change the distance between the two bulbs of the absorber to read "5 mm. maximum" rather than "5 mm."

Insert the following note under Fig. 1 to provide manufacturing tolerances:

NOTE.—In the case of those dimensions for which no specific tolerances are designated above, the permissible variation is ±10 per cent to the nearest millimeter, provided, however, that in no case the deviation be greater than 5 mm.

New Section.—Add a new Section 7 on Accuracy to read as follows:

7. *Accuracy.*—Duplicate determinations by the same operator should not differ by more than the amounts given in the following tabulation:

SULFUR FOUND, PER CENT	AVERAGE DEVIATION FROM MEAN, PER CENT SULFUR
Under 0.125	0.0025
0.125 to 0.25	0.005
0.25 to 0.50	0.01
Over 0.50	0.02

For different operators corresponding deviations may be double those given above.

Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 – 29 T).[2]—The following changes are recommended by Subcommittee IX on Precipitation (L. W. Parsons, chairman):

Section 4.—Change from its present form: namely,

4. *Centrifuge Tubes, A.S.T.M. Type.*—These tubes shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 cc. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube as follows:

RANGE	SCALE DIVISIONS	LIMIT OF ERROR	NUMBERED
0 – 0.5 cc.	0.05 cc.	0.02 cc.	½ cc.
0.5 – 3 "	0.1 "	0.05 "	1, 2, 3 "
3 – 5 "	0.5 "	0.2 "	4, 5 "
5 – 10 "	1.0 "	0.5 "	6, 8, 10 "
10 – 25 "	5.0 "	1.0 "	15, 20, 25 "
50 – 100 "	50.0 "	1.0 "	50, 100 "

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 697 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 409.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 694 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 406.

The shape is optional provided it does not conflict with the other requirements.

to read as follows:

4. The centrifuge tube, A.S.T.M. cone-shaped type shown in Fig. 1, shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 ml. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube. The length and outside diameter are optional provided they do not conflict with the other requirements. The value of the divisions for each range with limits of error are given in the following tabulation:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 0.1 ml....	0.05 ml.	0.02 ml.	....
0.1 to 0.3 "	0.05 "	0.03 "	....
0.3 to 0.5 "	0.05 "	0.05 "	½ ml.
0.5 to 1.0 "	0.1 "	0.05 "	1 "
1 to 3 "	0.1 "	0.1 "	2, 3 "
3 to 5 "	0.5 "	0.2 "	4, 5 "
5 to 10 "	1.0 "	0.5 "	6, 8, 10 "
10 to 25 "	5.0 "	1.0 "	15, 20, 25 "
25 to 100 "	25.0 "	1.0 "	50, 75, 100"

Figure 1.—Insert as Fig. 1 the accompanyng Fig. 1 (*b*) showing the A.S.T.M. Cone-Shaped Tube.

Section 5.—Add a new Section 5 to read as follows, renumbering the subsequent sections accordingly:

5. *Thermometer.*—The A.S.T.M. aniline point thermometer shall be identical with the A.S.T.M. paraffin wax melting point thermometer described in Section 6 of the Standard Method of Test for Melting Point of Paraffin Wax (A.S.T.M. Designation: D 87) of the American Society for Testing Materials.

Tentative Methods of Sampling Petroleum and Petroleum Products (D 270 − 27 T).[1]—Subcommittee XV on Sampling and Gaging (A. E. Flowers, chairman) desires to bring the section on Thief Sampling of these methods into agreement with the modification proposed last year in the A.S.T.M. Standard Methods of Testing Electrical Insulating Oils (D 117 − 27) by Committee D-9 on Electrical Insulating Materials.[2] The subcommittee accordingly recommends that Sections 55 to 59, inclusive, of the present methods be replaced by the revised sampling procedure appended hereto[3] as Sections 55 to 60, and that the remaining sections be renumbered accordingly.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 27, Part I, p. 896 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 341.

[2] See *Proceedings,* Am. Soc. Testing Mats., Vol. 29, Part I, p. 457 (1929).

[3] The revised sampling procedure has been incorporated in the revised Tentative Methods of Sampling Petroleum and Petroleum Products, see p. 1090.—ED.

Tentative Method of Test for Distillation of Crude Petroleum (D 285 – 29 T).[1]—The following changes are recommended by Subcommittee XXI on Crude Petroleum (A. J. Kraemer, chairman):

Section 8.—Change the second sentence to read as follows by the addition of the italicized words and the omission of the word in brackets:

> A [special] 300-cc. pipette *with unconstricted outlet, similar to* Fig. 3, is a convenient device for measuring charges, but an accurate graduate may be used if desired.

Figure 3.—Delete the calibration mark below the bulb, as it is intended that the pipette shall deliver 300 cc. when filled to the upper mark and drained.

ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD

The committee recommends the submission of the following tentative methods to letter ballot of the Society for adoption as standard:

Tentative Method of Test for Melting Point of Petrolatum (D 127–28 T),[2] slightly modified in accordance with recommendations of Subcommittee I on Petrolatum (W. H. Herschel, chairman) as follows:

Section 4.—Change from its present form: namely,

> 4. The beakers shall be of the tall form type and have a capacity of 600 cc.

to read as follows:

> 4. A transparent container of not less than 500-ml. capacity that will permit the immersion of the test tube to a depth of at least 75 mm. and still leave a depth of 15 mm. of water below the bottom of the test tube.

Section 5.—*(a)* In the second sentence change the temperature "180° F." to read "200° F." and add the following in parenthesis after this sentence:

> (This temperature may be taken with any general laboratory thermometer.)

In paragraph *(b)* change the third sentence to read as follows, by the addition of the italicized figures and the omission of those in brackets:

> The temperature of the bath shall be raised at a rate of [2° F.] *3° F.* per minute to 100° F., then at a rate of [1° F.] *2° F.* per minute until the first drop of petrolatum leaves the thermometer.

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[1] *Proceedings*, Am. Soc. Testing Mats. Vol. 29, Part I, p. 687 (1929); also 1929 Book of A.S.T.M Tentative Standards, p. 381.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 931 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 395.

Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline (D 130 – 27 T),[1] without revision.

Tentative Method of Test for the Determination of Autogenous Ignition Temperature (D 286 – 28 T).[2]—The following minor changes are recommended by Subcommittee XXVIII on Autogenous Ignition:

Section 2.—Change Paragraph (*a*) to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

> 2. (*a*) *Solder Bath.*—The solder bath shall consist of a round-bottomed iron pot about [4½] *5* in. in diameter and [3½] *5* in. in height, [and] filled with alloy to within about [1] *1½* in. of the top *before the flask is immersed.*

Introduce a new Paragraph (*b*) to read as follows and reletter the present paragraphs accordingly:

> (*b*) *Shield.*—A cylindrical, asbestos, metal-lined shield, approximately 13 in. in diameter, shall be provided to protect the solder bath from draughts.

Section 3.—Change this section from its present form to read as follows:

> 3. The alloy in the solder bath shall be melted and the flask partially submerged in the molten alloy so that the bottom of the flask is approximately ¾ in. from the bottom of the iron pot. It should be centered in the bath and shall not touch the walls of the iron pot at any point. The thermocouple (or thermometer) shall be placed and held firmly by suitable clips in the solder bath in such a position that its end shall be about ¾ in. from the bottom of the bath and ¼ in. from the side of the flask. With the draught shield in position, the temperature of the bath shall be brought to and held at a temperature near the probable ignition temperature of the sample under test. Various amounts of the sample measured by a micro pipette shall be admitted to the flask until an amount of sample is determined which will produce ignition. In successive tests at least two minutes shall be allowed to elapse after each addition of a sample, and the gases and vapors completely displaced in the interval between tests by the aid of a slow stream of clean air. If ignition takes place when one of the charges is added, the temperature should be lowered about 5° C. and the process repeated, starting with the number of drops that ignited in the first instance. A larger and smaller number of drops should also be tried in order to be sure that the volume of test sample giving the lowest temperature of ignition shall be included in the tests. The operator should proceed, in general, in this manner, raising or lowering the temperature by approximately 5° C. intervals, according as ignition does not or does take place, holding each temperature approximately constant during all trials at that temperature, until an indicated temperature is found at which ignition takes place, but at 5° C. below which ignition fails to take place. The minimum indicated ignition temperature may then be determined by repeated trials between the indicated temperature and a temperature 5° C. less. Results should be duplicable to within ± 2° C. of the indicated temperature.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 926 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 373.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 915 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 374.

In autogenous ignition tests with the above apparatus it is, in general, better to work downward from a higher temperature at first by intervals of from 5 to 20° C., and later by lowering the temperature by approximately 5° C. intervals.

WITHDRAWAL OF TENTATIVE REVISION OF A STANDARD METHOD

The committee recommends the withdrawal of the following tentative revision of a standard method:

Standard Method of Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue (D 189 – 28).[1]—The revision published as tentative in 1929[2] is recommended for withdrawal by Subcommittee XXIII on Carbon Residue (F. R. Baxter, chairman), because of the recommended revision of this standard method given earlier in this report.[3]

The recommendations appearing in this report have been submitted to letter ballot of the committee, which consists of 89 meembes; 60 ballots have been returned and 29 members have refrained from voting. The result of the letter ballot is shown in Table I.

TABLE I.—ANALYSIS OF LETTER BALLOT VOTE.

Item	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE STANDARDS			
Tentative Method of Test for Vapor Pressure of Natural Gasoline (Reid Method)	51	0	9
Tentative Method of Test for Dilution of Crankcase Oil	53	2	5
II. REVISION OF STANDARD METHODS			
Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 - 27)	53	2	5
Test for Water and Sediment in Petroleum Products by Means of Centrifuge (D 96- 28)	57	2	1
Test for Cloud and Pour Points of Petroleum Products (D 97 - 28)	57	1	2
Test for Burning Quality of Kerosine Oils (D 187 - 27)	49	1	10
Test for Burning Quality of Mineral Seal Oil (D 239 - 27)	49	0	11
Test for Burning Quality of Long-Time Burning Oil for Railway Use (D 219 - 27)	49	0	11
Test for Distillation of Natural Gas Gasoline (D 216 - 27)	50	2	8
Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 28)	55	1	4
III. ADVANCEMENT OF TENTATIVE REVISIONS OF STANDARD METHODS TO STANDARD			
Test for Viscosity of Petroleum Products and Lubricants (D 88 - 26)	60	0	0
Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (D 86 - 27)	56	2	2
Test for Water in Petroleum Products and Other Bituminous Materials (D 95 - 28)	59	0	1
IV. REVISION OF TENTATIVE STANDARDS			
Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287 - 28 T)	57	1	2
Tentative Method of Test for Sulfur in Motor Fuels, Naphthas and Illuminating Oils (Lamp Method) (D 90 - 29 T)	55	0	5
Tentative Method of Test for Precipitation Number of Lubricating Oils (D 91 - 29 T)	54	1	5
Tentative Methods of Sampling Petroleum and Petroleum Products (D 270 - 27 T)	56	0	4
Tentative Method of Test for Distillation of Crude Petroleum (D 285 - 29 T)	51	0	9
V. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Method of Test for Melting Point of Petrolatum (D 127 - 28 T)	54	1	5
Tentative Method of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline (D 130 - 27 T)	55	2	3
Tentative Method of Test for the Determination of Autogenous Ignition Temperatures (D 286 - 28 T)	41	3	16
VI. WITHDRAWAL OF TENTATIVE REVISION OF STANDARD METHOD			
Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) (D 189 - 28)	54	1	5

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[1] 1928 Supplement to Book of A.S.T.M. Standards, p. 129.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 870 (1929).

[3] See p. 770.—ED.

This report has been submitted to letter ballot of the committee, which consists of 89 members; 60 members returned their ballots, of whom 56 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

F. A. HULL,
Chairman.

R. P. ANDERSON,
Secretary.

EDITORIAL NOTE

The proposed Tentative Methods of Test for Vapor Pressure of Natural Gasoline (Reid Method) and for Dilution of Crankcase Oil were accepted for publication as tentative and appear on pages 1139 and 1112.

The proposed immediate revisions of the Standard Methods of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products, Test for Cloud and Pour Points of Petroleum Products, Test for Burning Quality of Kerosine Oils, Test for Burning Quality of Mineral Seal Oil and Test for Burning Quality of Long-Time Burning Oil for Railway Use, were accepted by a unanimous vote at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 491, 481, 462, 472 and 468.

The revisions proposed for immediate adoption in the Standard Methods of Test for Water and Sediment in Petroleum Products by Means of Centrifuge, Test for Distillation of Natural Gas Gasoline and Test for Carbon Residue of Petroleum Products (Conradson Carbon Residue) were accepted as revised on the floor of the annual meeting, see Summary of Proceedings, page 20, and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Book II, pages 560, 500 and 477.

The tentative revisions of the Standard Methods of Test for Viscosity of Petroleum Products and Lubricants, Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products and Test for Water in Petroleum Products and Other Bituminous Materials, presented in 1929, were approved at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The standard methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 550, 491 and 556.

The proposed revisions of the Tentative Methods of Test for Sulfur in Motor Fuels, Naphthas and Illuminating Oils, of Sampling Petroleum and Petroleum Products and Test for Distillation of Crude Petroleum were accepted. The methods as revised appear on pages 1134, 1090 and 1115.

The proposed revisions of the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer and Test for Precipitation Number of Lubricating Oils, as revised on the floor of the annual meeting, see Summary of Proceedings, pages 22 and 23, were accepted. The methods in their revised form appear on pages 1122 and 1130.

The Tentative Methods of Test for Detection of Free Sulfur and Corrosive Sulfur Compounds in Gasoline, without revision, Test for Melting Point of Petrolatum and Test for the Determination of Autogenous Ignition Temperatures, as revised, were approved at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 488, 532 and 489.

REPORT OF SUBCOMMITTEE V ON VISCOSITY

Subcommittee V on Viscosity desires to call attention to the following points which are important if the highest possible accuracy is to be obtained in the determination of viscosity by the Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (D 88 - 26).[1] These points, several of which are mentioned in the standard method, have been suggested by the Subcommittee on Viscosity Standards of the Committee on Testing Methods and Specifications of the American Petroleum Institute. Duplicate determinations on the same apparatus should check within 0.5 per cent provided the following suggestions are followed exactly. The references are to sections of the method.

Section 2(a).—Dimensions of the oil tubes should be checked, particularly the height and condition of the overflow rim above the outlet tube. This rim if worn down or damaged by abuse, reduces the oil head, thus vitiating results. A frequent cause for erroneous viscosity results is a burr at the upper end of the outlet tube. The presence of such a burr may be detected by looking through the lower end of the tube with a magnifying glass, using a white background.

The receiving flask should be calibrated and should be accurate within ± 0.05 ml. With the present tolerance of 60 ml. ± 0.15 ml., the time of flow of an oil of 300 viscosity at 100° F. as determined in two receiving flasks of 59.85 and 60.15 ml. capacity would differ by 1.5 seconds, assuming the time of flow to be proportional to the volume delivered, which is a fair approximation. The receiving flask should be washed thoroughly with pure benzene and dried with an air blast between determinations.

Section 2(c).—All thermometers used should be calibrated to ± 0.05° F. Errors of 0.2 to 0.4° F. are not uncommon, particularly in the 210° F. instruments.

Section 4, First Paragraph.—The variation of the bath temperature from the predetermined equilibrium temperature must not exceed the limits established and should be as small as possible. This is particularly important in tests at the lower temperatures where the influence of temperature on viscosity is most pronounced.

Second Paragraph.—The bath liquid should be water wherever barometric and other conditions permit, to eliminate in so far as possible variations between different laboratories in the bath temperatures necessary for thermal equilibrium.

The viscosimeter *must* be protected from draughts and rapid temperature changes, and the room temperature should be between 68 and 86° F.

Third Paragraph.—All oil must be passed through a 100-mesh wire strainer.

Fourth Paragraph.—In cleaning the barrel, pure benzene should be used, unless it is known that the oil to be tested contains no asphaltic matter which would be precipitated as a solid by light naphthas. After thorough washing of the barrel and removal of all solvent from the overflow cup, a quantity of the oil to be tested, sufficient to wet thoroughly all the inner surface of the oil tube, should be poured in and allowed to drain out. Any oil which collects in the cylindrical collar below and surrounding the outlet tube should be removed by wiping with tissue paper, as otherwise it might run down after insertion of the cork stopper and fall into the flask on removal of the stopper.

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[1] 1927 Book of A.S.T.M. Standards. Part II, p. 427.

Fifth Paragraph.—One common practice which can lead to errors is that of superheating the oil outside the viscosimeter to too high a temperature. This, and the practice of "pokering" or heating of the oil in the cup by the immersion therein of hot bodies is not to be countenanced.

Every precaution should be taken to see that the oil tube thermometer does not touch the orifice in stirring the oil.

The cork *must* be snapped from its position with a quick jerk to minimize differences in the suction that will be applied to the oil.

A stopwatch *must* be used for referee or standardization testing, as timing devices actuated by a pendulum beating seconds may be in error by 0.7 to 0.8 seconds at the end of the test.

With an oil of high viscosity, the oil stream should strike the receiving flask as close to the constricted neck as possible.

The subcommittee recommends that the tentative revision of the Standard Methods of Test for Viscosity of Petroleum Products and Lubricants (D 88 – 26) proposed last year[1] be advanced to standard and incorporated in the standard methods.

Respectfully submitted on behalf of the subcommittee,

W. H. HERSCHEL,
Chairman.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 869 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 823.

REPORT OF SUBCOMMITEE XXV ON CRANKCASE DILUTION

The 1929 report of Subcommittee XXV[1] gave the results of tests on used crankcase oils by two different methods, a vapor-temperature method and a steam-distillation method. It was indicated that two modifications of the latter method, independently developed, were being considered. It was shown that with the samples in question, reproducible results were obtained in different laboratories by both of these methods. The objection which was raised to the vapor-temperature method was the possibility of cracking with samples of little or no dilution. The steam-distillation method developed by the Standard Oil Development Co. required several hours for a determination, and development work was not entirely complete on the steam-distillation method proposed by the chairman's laboratory.

Further work on the vapor-temperature method in the chairman's laboratory has had to do mainly with a suggestion by Mr. H. T. Kennedy that a given amount of diluent be added to the sample before running the dilution. The results indicated that this is a useful modification in that it lowers the bottom temperature in the case of samples which have little or no dilution and therefore lessens the possibility of cracking. The results obtained were substantially the same as by the original vapor-temperature method. Altogether, it was indicated that this might be considered an improvement in the method, although it should be stated that this study has not really yielded any definite examples of difficulties with the vapor-temperature method. Some data are given in a later section showing the results of cooperative work by this modification.

Further work on the steam-distillation method in the chairman's laboratory has been successful in developing a method which is quite accurate and reasonably rapid, requiring generally not over an hour to complete a test. This test subjects the oil to severe steam distillation and long continuation of the test gives high results due to steam distillation of the lighter ends in the case of light motor oils. This difficulty has been overcome by adopting empirical limits as to rate of heating and duration of the test. The apparatus which has been chosen involves the use of a 25-ml. sample with a distillation trap of 12.5-ml. capacity. With the use of a 1-liter flask and various means to minimize bumping no trouble with frothing over has been observed.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 373 (1929).

With the vigorous boiling incidental to this method it was soon apparent that an arbitrary end point was necessary in the case of many oils. In general, this is taken care of by specifying that the test is complete when the amount of diluent increases by not more than 0.1 ml. in 15 minutes. In the case of some oils, however, there is present an appreciable amount of fairly heavy material, volatile with steam, and it was found that the test might be continued for hours with an increase of perhaps 0.2 ml. every 15 minutes. There was added to take care of this situation an additional criterion for the end point which stated that the tests should be arbitrarily discontinued if the volume of the diluent was less than a certain amount in a given time. These figures were based on a large number of determinations which show definitely that with the rate as desired it could be assumed that a diluent of the ordinary type would all be distilled over in a definite time. With the procedure substantially as described in the proposed tentative method appended hereto,[1] a set of cooperative tests was made by this steam-distillation method.

In addition to the methods described above, the 1929 cooperative tests included the vapor-temperature distillation method as previously described[2] and the steam-distillation method suggested by the Standard Oil Development Co. Table I gives the results of these tests on three used crankcase samples. It will be observed that results on samples Nos. 29-6 and 29-7, which show dilutions over 15 per cent, are reasonably concordant by all four methods. In the case of sample No. 29-5, which shows a low dilution, results were in general less satisfactory, although very good by Method C. The modification of the vapor-temperature method (Method B) which involved adding five per cent of diluent before the test and subtracting this figure from the result was not more successful in giving concordant results than the simple vapor-temperature method (Method A). It may be noted that the results of Laboratory No. 9 by Method D are markedly low, indicating that the rate of distillation was too slow. With the provision subsequently incorporated of a check run on a known sample, widely discrepant results such as these will be eliminated. Excluding this set the average percentage deviation from the mean for the samples in Table I by Method D were 5.9 per cent, 4.2 per cent, and 3.8 per cent, which is quite as good as obtained by any other method.

As a result of these tests it was decided to confine attention to Method D for steam distillation. The rapidity of this method is in its favor, while it was generally considered that the time required for Method C is too great. The objections to the vapor-temperature method still remained and there was not entire agreement regarding the use of Method B, one objection being the possibility of overlooking the step of subtracting the diluent added.

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[1] See p. 1112.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 373 (1929).

TABLE I.—TEST RESULTS ON USED CRANKCASE OILS BY SEVERAL METHODS, PER CENT DILUTION.

Laboratory	Sample No. 29-5				Sample No. 29-6				Sample No. 29-7			
	Vapor-Temperature Method		Steam-Distillation Method		Vapor-Temperature Method		Steam-Distillation Method		Vapor-Temperature Method		Steam-Distillation Method	
	A[1]	B[2]	C[3]	D[4]	A[1]	B[2]	C[3]	D[4]	A[1]	B[2]	C[3]	D[4]
No. 1	2.5 3.5	2.5 ...	3.2 ...	2.4 2.8	14.0	14.0	18.2	18.0 17.2	12.5	12.0 12.0	17.6	16.0 16.8
No. 2	2.5 2.5 2.5	... ...	3.2 3.4 2.8	2.4 2.4 2.8	15.0 15.5 15.5	....	18.6 18.8 18.8	17.2 17.2 16.7	[a] [a] [a]	....	17.3 16.7 16.8	16.0 15.6 16.0
No. 3	3.0 3.0 ...	3.0 3.0 ...	3.2 3.4 ...	2.8 2.8 2.8	16.0 16.0	16.0 16.0	17.3 17.4	16.0 15.6 16.0	15.5 15.5	15.5 15.5 16.0	16.2 16.4	15.2 14.8 14.8
No. 4	2.5 2.5	... ...	3.1 ...	3.0 2.8	15 3 15.5	....	....	17.6 17.2	13.0 13.3	....	....	16.6 16.6
No. 5	5.5 5.5 ...	3.75 4.75 5.0	2.8 3.0 ...	2.4 2.8 2.8	18.0 18.5	17.5 16.5	17.0 15.4	16.4 15 6 16.4	17.5	18.0 17.0	16.8 15.4	16.0 15.2 16.4
No. 6	...	...	3.1	3.2	....	....	17.6	18.4	....	....	15.9	16.0
No. 7	... ...	3.4 3.4	... ...	3.2 3.2	....	....	16.2 17.0	17.6 17.2	....	....	15.3 14.9	16.8 17.2
No. 8	...	5.5	3.4	...	....	16.5	16.7	....	....	17.5	16.5	....
No. 9	... ...	... ...	... ...	0.4 0.8 ...	....	....	....	8.4 11.6 11.2	....	....	....	8.8 10.0 10.8
Average, all laboratories	3.23	3.81	3.14	2.55	15.93	16.08	17.42	15.88	14.50	15.44	16.32	15.03
Average percentage deviation from mean	25.0	26.0	5.0	15.3	6.0	4.7	4.8	11.2	11.2	11.1	3.9	11.0

[1] As used in the tests described in the 1929 Report, see *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 373 (1929).

[2] As modified by Mr. H. T. Kennedy, involving the addition of 5 per cent of diluent before the test and subtracting this figure from the result.

[3] As used by the Standard Oil Development Co.

[4] As developed in the chairman's laboratory.

[a] Foaming.

It was seen that Method D is about as accurate as Method C for samples of higher dilution but not as accurate for samples of low dilution. A final set of samples was distributed for test by Method D and particular attention was paid to the case where a light oil containing an appreciable amount of volatile material is under test. In this series of tests two fresh oils were submitted, one (sample No. 30-1) a light naphthenic base oil of approximately 300 seconds viscosity at 100° F. and 350° F. flash point. The other (sample No. 30-2) was an oil of about 75 seconds viscosity at 210° F. It was known that the light oil would give 2 or 3 per cent dilution by the steam-distillation method if the test were continued for some time. The fresh oils were tested by adding known amounts, 3 and 15 per cent, of oleum spirits, a naphtha having a boiling range of approximately 300 to 420° F. The test with 3-per-cent dilution on oil Sample No. 30-1, therefore, constitutes about the most difficult situation that this steam-distillation method could meet; also the use of an oil having a viscosity as high as the second oil is rather unusual. With the optimum rate of distillation it had been found that a dilution of 3 per cent would be practically all distilled over in 15 minutes and in the cooperative tests of 1930 it was suggested that the distil-

TABLE II.—TEST RESULTS ON OILS OF KNOWN DILUTION BY METHOD D (STEAM-DISTILLATION), PER CENT DILUTION.

Laboratory	Time, minutes	Sample No. 30-1						Sample No. 30-2					
		3 Per Cent Added Dilution			15 Per Cent Added Dilution			3 Per Cent Added Dilution			15 Per Cent Added Dilution		
		(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)	(1)	(2)	(3)
No. 1....	15	3.0	3.4	...	....	13.8	....	2.6	2.6	...	11.6	10.8	....
	30	3.6	4.0	...	15.0	15.4	....	3.0	2.8	...	13.2	13.4	....
	45	4.4	4.4	...	15.8	16.4	....	3.0	2.8	...	13.8	14.4	....
	60	...	...	...	16.2	17.6	....	...	...	...	14.0	14.4	....
	75	...	...	...	17.2	18.0	....	...	...	...	....	....	....
	90	...	...	...	17.2	18.0	....	...	...	...	....	....	....
No. 2....	120 or 180	9.2	9.2	...	19.6	20.0	20.0	2.4	2.8	2.8	13.2	14.8	13.2
No. 3....	15	3.0	3.0	3.0	....	....	....	2.8	3.0	3.0	....	....	....
	30	...	...	...	15.0	15.0	15.0	...	...	...	15.0	14.8	14.8
No. 4....	15	3.0	3.2	...	12.8	13.6	....	1.2	1.2	...	12.8	12.0	....
	30	...	...	...	15.6	16.0	....	2.0	1.6	...	13.6	14.0	....
	45	...	...	...	17.2	16.8	....	...	...	...	14.4	14.4	....
	60	...	...	...	18.0	17.2	....	...	...	...	14.0	14.4	....
No. 5....	15	3.0	3.0	...	12.8	11.2	....	1.8	1.8	...	11.2	11.6	....
	30	4.0	4.4	...	14.8	14.8	....	2.6	2.6	...	13.6	13.2	....
	45	4.8	4.8	...	15.6	15.6	....	2.8	2.8	...	14.8	14.0	....
	60	...	...	...	16.0	16.0	....	...	...	...	14.8	14.4	....
	90	...	...	...	17.2	16.8	....	...	...	...	....	....	....
No. 6....	15	0.8	0.8	...	8.6	9.2	....	1.8	1.8	...	10.0	10.4	....
	30	1.8	2.2	...	12.8	12.0	....	2.6	2.6	...	12.0	12.4	....
	45	2.6	2.6	...	13.2	12.4	....	2.8	2.8	...	12.8	13.2	....
	60	3.0	3.0	...	13.6	13.2	....	2.8	2.8	...	13.2	13.6	....
	75	...	...	...	14.8	13.6	....	...	...	...	13.6	14.0	....
	90	...	...	...	14.8	13.6	....	...	...	...	13.6	14.0	....
No. 7....	15	3.0	3.0	3.0	12.8	12.8	12.8	1.0	1.2	1.2	11.4	11.8	11.8
	30	3.8	3.8	3.8	14.2	14.2	14.2	1.4	1.8	1.8	12.6	13.0	13.2
	45	...	...	...	16.4	16.0	16.4	1.8	2.2	2.2	13.0	13.2	13.2
	60	...	...	...	17.2	17.2	17.2	1.8	2.2	2.2	13.0	13.2	13.2
	75				17.8	17.4	17.4						
	90				18.0	17.6	17.8						

lation be considered complete if the amount of diluent were less than 1 ml. in 15 minutes. This was a feature in addition to that used in the preceding set of tests. The results of the tests on the two fresh oils with added dilution are shown in Table II where, for most of the laboratories, the complete results for given periods are indicated. It was found in some cases that with oil Sample No. 30-1 containing 3 per cent added dilution a result closely approximating 3 per cent was obtained in 15 minutes. However, in other cases the rate of distillation was slower and the result was low. With the heavy oil, Sample No. 30-2, several of the laboratories showed low results for 3 per cent added diluent in 15 minutes. An inspection of the results shows that for all cases a stopping period of 30 minutes is the least that should be specified. Also, it seems to be impossible to specify closely the maximum running time for high dilutions and the inevitable result is that oils of the type of Sample No. 30-1 will show high dilution. The procedure as shown in the proposed tentative method gives results which on the whole are the closest approximation for all cases.

TABLE III.—TEST RESULTS ON USED CRANKCASE OILS BY METHOD D (STEAM-DISTILLATION).

Laboratory	Sample No. 30-3		Sample No. 30-4		Sample No. 30-5	
	Dilution, per cent	Time, minutes	Dilution, per cent	Time, minutes	Dilution, per cent	Time, minutes
No. 1	11.2 11.2 12.0	60	12.0 12.8 12.4	60	6.0 6.8 7.2	30
No. 2	12.8 12.4 12.0	.. .. ..	13.6 14.0 12.8	.. .. ..	7.6 7.6 ...	.. .. ..
No. 3	11.2 11.6 11.2	30	10.8 10.4 10.8	30	6.0 6.4 6.4	30
No. 4	11.6 12.4	60	11.6 12.0	60	6.8 6.8	30
No. 5	14.0 13.8	60	11.2 10.8 11.2	60	6.8 7.2	45
No. 6	10.0 11.6	60 70	9.2 8.8	75 60	5.4 5.4	60 60
No. 7	11.6 12.0 11.6	60	12.0 11.8 12.0	60	6.6 6.8 6.8	45
Average, all laboratories	11.95	..	11.60	..	6.64	..
Average per cent deviation from mean	5.8	..	8.3	..	7.3	..

Table III shows the results by Method D on three samples of used crankcase oils. It will be observed that the agreement is quite good and the indications are that for used oils, in general, the method will be entirely successful. It might be added that the difficulties which were experienced with Sample No. 30-1 will be met with very seldom in the case of actual samples.

The subcommittee recommends the adoption of the Proposed Tentative Method of Test for Dilution of Crankcase Oil (Method D) as appended hereto.[1]

Respectfully submitted on behalf of the subcommittee,

T. H. ROGERS,
Chairman.

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[1] See p. 1112.—ED.

REPORT OF SUBCOMMITTEE XXVIII ON AUTOGENOUS IGNITION OF PETROLEUM PRODUCTS

During the past year cooperative test work has been conducted at different laboratories, primarily to obtain further information on the duplicability of tests of liquid petroleum products by the Tentative Method of Test for the Determination of Autogenous Ignition Temperatures (D 286 – 28 T).[1] It was thought that this cooperative effort would also yield some useful information leading to possible improvements in the present form of apparatus and method of testing for ignition temperatures. Six members of Committee D-2, not members of the subcommittee, expressed a willingness to cooperate in this work.

Test Program:

The following liquids were selected by the subcommittee for test:

Gasoline of approximately fighting aviation grade
Ordinary motor gasoline
Heavy cleaners solvent (Stoddard solvent specifications)
Kerosine
Lubricating oil of approximately motor grade
Ethyl ether
Acetone
Carbon disulfide
Heptane

It was considered necessary owing to variations in petroleum products from different sources to arrange to have uniform samples in sealed containers sent to members engaged in the test work. Uniform samples of the first five liquids mentioned above were prepared by Mr. J. B. Terry, Chief Chemist of the Standard Oil Co. of California, and were shipped December, 1928, to members of this subcommittee and also to other members of Committee D-2 cooperating in the work.

Members were requested to employ the apparatus and method of test described in detail in the Tentative Method of Test D 286 – 28 T.[1]

Results:

The results of these tests are recorded in Table I. The average of the results and the average deviation from the mean are as follows:

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 915 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 374.

	AVERAGE IGNITION TEMPERATURE, DEG. CENT.	MEAN DEVIATION FROM AVERAGE IGNITION TEMPERATURE, DEG. CENT.
Aviation gasoline	303	12
Motor gasoline	284	13
Stoddard solvent	277	11
Kerosine	244	8
Lubricating oil	347	26
Ethyl ether	220	46
Acetone	583	37
Carbon disulfide	135[a]	14
Average mean deviation		21
Average mean deviation of aviation gasoline, motor gasoline, Stoddard solvent, kerosine and lubricating oil		14° C.

[a] A laboratory not in the group included in Table I reported 107° C. and 120° C. for carbon disulfide in oxygen and in air, respectively; the lag in both cases being 10 seconds.

Comments on Results:

The average deviation in results was somewhat larger than was expected. It should be noted that some of the workers did not adhere strictly to the requirements of the test procedure, which, however, are not entirely clear on all points.

In cases where the results are much higher than the average, the lag,[1] if reported, will be found to be relatively low as indicated in the result of laboratory No. 1 on aviation gasoline. In general, the lag decreases as the temperature of the flask is raised above the autogenous ignition temperature. It would be interesting, therefore, to study the lag (not reported) in tests on carbon disulfide, ethyl ether, aviation gasoline and lubricating oil by laboratory No. 2 and on acetone by laboratory No. 4, which appear to be too high.

Comments on the Method:

While it is important to use as a working basis, theories on ignition and combustion that appear to be at least of temporary service, it is well to keep in mind that the actualities of autogenous ignition have not as yet been fully explained in terms of our present knowledge. The subject is complex, and the following remarks are intended to be of an introductory nature.

It appears that when a flammable mixture of vapor and air is heated to ignition by contact with a solid surface, as for example, the walls of the flask, there is first a period (lag) of preliminary[2] or initial chemical reactions followed by the appearance of flame.

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[1] Lag is considered to be the time interval between admission of the sample to flask and the appearance of the flame.

[2] Known as the pre-flame period.

TABLE I.—RESULTS OF COOPERATIVE TESTS ON AUTOGENOUS IGNITION OF VARIOUS LIQUIDS.

Liquid	Laboratory	Gravity, deg. A.P.I.	Initial Boiling Point, deg. Cent.	End Point, deg. Cent.	Barometer, mm. Mercury	Ignition Chamber			Source of Heat	Heat Transfer Medium	Volume Introduced		Temperature Measuring Instrument	Lag, seconds	Ignition Temperature, deg. Cent.		Remarks
						Volume, ml.	Shape	Material			Drops	milliliter			Observed	Mean	
Aviation Gasoline	No. 1	63.6	44	162	752	160	Conical	Pyrex	Gas Flame	Solder Bath	3	0.10	Thermocouple	6	290	290	280° C. obtained for ordinary gasoline.
	No. 2	63.9	57	163	...	165	"	"	" "	"	..	....	Nitrogen Thermometer	..	329	329	305° C. obtained in glass-stoppered flask.
	No. 3	62.0	44	...	...	158	"	"	" "	"	4	0.079	3-in. Immersion Thermometer	50	278	278	See Note.
	No. 4	....	..	...	...	125	"	"	" "	"	..	0.03	Thermocouple	13	295	295	Pyrex No. 3 flask.
	No. 5	63.8	43	164	...	160	"	"	" "	"	4	0.08		7	310	310	1 drop gave 352° C. with 4 seconds lag; 2 drops, 324° C. with 5 seconds lag; 3 drops, 313° C., with 6 seconds lag.
											5	0.10		6	310		
	No. 6	Tests made in accordance with A.S.T.M. Tentative Method[a]												..	298–305	301	8 tests, difference between maximum and minimum 7° C.
	No. 7	63.8	41	163	...	160	Conical	Pyrex	Gas Flame	Solder Bath	6	0.10	Nitrogen Thermometer	8	...	312	Flask A, 312° C.; Flask B, 322° C.
Motor Gasoline	No. 1	52.5	51	215	756	160	"	"	" "	"	3	....	Thermocouple	6	273	273	
	No. 2	52.7	42	213	...	165	"	"	" "	"	..	....	Nitrogen Thermometer	..	302	302	289° C. obtained in glass-stoppered flask.
	No. 3	51.1	53	...	...	158	"	"	" "	"	3	0.060	3-in. Immersion Thermometer	40	268	268	See Note.
	No. 4	....	..	...	...	125	"	"	" "	"	..	0.02	Thermocouple	21	279	279	Pyrex No. 3 flask.
	No. 5	52.7	53	214	...	160	"	"	" "	"	3	0.06		7	304	307	1 drop gave 321° C. with 5 seconds lag; 5 drops, 321° C. with 6 seconds lag.
											4	0.08		..	310		
	No. 6	Tests made in accordance with A.S.T.M. Tentative Method[a]												..	268–274	270	8 tests, difference between maximum and minimum 6° C
	No. 7	52.8	52	214	...	160	Conical	Pyrex	Gas Flame	Solder Bath	6	0.10	Nitrogen Thermometer	10	...	290	Flask A, 290° C.; Flask B, 290° C.
Stoddard Solvent	No. 1	42.7	152	207	753	160	"	"	" "	"	3	....	Thermocouple	5	268	268	
	No. 2	42.8	...	205	...	165	"	"	" "	"	..	....	Nitrogen Thermometer	..	294	294	279° C. obtained in glass-stoppered flask.
	No. 3	42.4	79	...	...	158	"	"	" "	"	2	0.039	3-in. Immersion Thermometer	35	266	266	See Note.
	No. 4	....	...	...	...	125	"	"	" "	"	..	0.02	Thermocouple	20	272	272	Pyrex No. 3 flask.
	No. 5	42.7	151	205	...	160	"	"	" "	"	2	0.04		6	263	263	1 drop gave 321° C. with 4 seconds lag; 4–5 drops gave 313–316° C. with 5–6 seconds lag.
											3	0.06		7	263		
	No. 6	Tests made in accordance with A.S.T.M. Tentative Method[a]												..	278–285	280	8 tests, difference between maximum and minimum 7° C.
	No. 7	45.1	150	207	...	160	Conical	Pyrex	Gas Flame	Solder Bath	5	0.08	Nitrogen Thermometer	6	...	301	Flask A, 301° C.; Flask B, 311° C.
Kerosine	No. 1	43.3	192	238	753	160	"	"	" "	"	3	....	Thermocouple	14	238	238	
	No. 2	43.3	...	...	...	165	"	"	" "	"	..	....	Nitrogen Thermometer	..	229	229	220° C. obtained in glass-stoppered flask.
	No. 3	43.0	96	...	...	158	"	"	" "	"	3	0.066	3-in. Immersion Thermometer	57	244	244	See Note.
	No. 4	....	...	...	...	125	"	"	" "	"	..	0.02	Thermocouple	115	240	266	Pyrex No. 3 flask.
												0.02		60	245		
												0.02		29	254		
	No. 5	43.2	193	241	...	160	"	"	" "	"	2	0.04		17	249	251	1 drop gave 271° C. with 6 seconds lag.
											5	0.10		17	254		
	No. 6	Tests made in accordance with A.S.T.M. Tentative Method[a]												..	238–246	242	8 tests, difference between maximum and minimum 8° C.
	No. 7	43.7	192	242	...	160	Conical	Pyrex	Gas Flame	Solder Bath	8	0.13	Nitrogen Thermometer	49	...	238	Flask A, 243° C.; Flask C, 238° C.

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[a] Tentative Method of Test for the Determination of Autogenous Ignition Temperatures (A.S.T.M. Designation: D 286 – 28 T), *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 915 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 374.

NOTE.—Solder Bath was stirred in these tests. Flask was immersed in solder two thirds of height. Apparatus was mounted in an asbestos-lined box. Iron pot for solder bath was 5 in.

TABLE I.—RESULTS OF COOPERATIVE TESTS ON AUTOGENOUS IGNITION OF VARIOUS LIQUIDS—*Continued.*

Liquid	Laboratory	Gravity, deg. A.P.I.	Initial Boiling Point, deg. Cent.	End Point, deg. Cent.	Barometer, mm. Mercury	Ignition Chamber			Source of Heat	Heat Transfer Medium	Volume Introduced		Temperature Measuring Instrument	Lag, seconds	Ignition Temperature, deg. Cent.		Remarks
						Volume, ml.	Shape	Material			Drops	milliliter			Observed	Mean	
Lubricating Oil	No. 1	20.3	...	...	...	160	Conical	Pyrex	Gas Flame	Solder Bath	8	....	Thermocouple............	..	264	264	Air introduced by bulb.
	No. 2	20.3	...	...	...	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	375	375	367° C. obtained in glass-stoppered flask.
	No. 3	20.9	165	...	...	158	"	"	" "	"	4	0.096	3-in. Immersion Thermometer	10	359	359	See Note.
	No. 4	....	...	...	...	125	"	"	" "	"	..	0.03	Thermocouple............	7	357	357	Pyrex No. 3 flask.
	No. 5	20.4	...	...	...	160	"	"	" "	"	2	0.04	....	5	368	368	1 drop gave 379° C. with 7 seconds lag.
											5	0.10	....	7	368		
	No. 6	Tests made in accordance with A.S.T.M. Tentative Method[a]												..	338–345	341	8 tests, difference between maximum and minimum 7° C.
	No. 7	....	...	...	...	160	Conical	Pyrex	Gas Flame	Solder Bath	3	0.05	Nitrogen Thermometer.....	6	...	365	Flask A, 365° C; Flask C, 365° C.
Ethyl Ether	No. 1	....	...	...	...	160	"	"	" "	"	..	....	....	..	180	180	
	No. 2	....	...	...	...	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	293	293	287° C. obtained in glass-stoppered flask.
	No. 3	....	34	...	760	158	"	"	" "	"	5	0.099	3-in. Immersion Thermometer	25	177	177	See Note.
	No. 4	....	...	...	...	150	"	"	" "	"	..	....	Thermocouple...........	..	188	188	C_2H_5OH (0.3 per cent)–186° C. in round 125-cc. Pyrex flask.
														..	195	195	U. S. P.—193° C. in round 125-ml. Pyrex flask.
	No. 5	....	...	...	...	160	"	"	" "	"	2	0.04	....	3	316	310	Lag very short.
											3–5	0.06–0.10	....	3–4	310		
Acetone	No. 1	....	...	...	...	160	"	"	" "	"	..	....	....	15	565	...	
	No. 2	....	...	...	...	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	over 538	...	Gas flame controlled with micrometer needle valve.
	No. 3	....	56	...	760	158	"	"	" "	"	1	0.019	Thermocouple............	15	546	546	See Note.
	No. 4	....	...	...	...	150	"	"	" "	"	..	....	Thermocouple............	..	639	639	636° C. in round 125-ml. Pyrex flask.
Carbon Disulfide	No. 1	....	...	...	...	160	"	"	" "	"	..	....	....	10–15	110	...	
	No. 2	....	...	...	...	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	160	160	151° C. was obtained in stoppered flask.
	No. 3	....	46	...	760	158	"	"	" "	Castor Oil Bath	4	0.079	3-in. Immersion Thermometer	4	133	133	Flashes obtained below 133° C., but not recorded.
	No. 4	....	...	...	...	150	"	"	" "	Solder Bath	..	....	Thermocouple............	..	127	127	125° C. in round 125-ml. Pyrex flask.
Heptane	No. 2	....	98.3	...	769	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	258	258	Normal heptane—237° C. was obtained in glass-stoppered flask.
	No. 2	....	93.6	97.5	...	165	"	"	" "	"	..	....	Nitrogen Thermometer.....	..	301	301	Petroleum heptane—294° C. was obtained in glass-stoppered flask.
	No. 3	....	98.3	...	769	158	"	"	" "	"	5	0.099	3-in. Immersion Thermometer	45	228	228	See Note.

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[a] Tentative Method of Test for the Determination of Autogenous Ignition Temperatures (A.S.T.M. Designation: D 286 - 28 T), *Proceedings*, Am. Soc. Testing Mats., Vol 28, Part I, p. 915 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 374.

NOTE.—Solder Bath was stirred in these tests. Flask was immersed in solder two thirds of height. Apparatus was mounted in an asbestos-lined box. Iron pot for solder bath was 5 in. in inside diameter and 4½ in. tall with walls $\frac{5}{32}$ in. thick.

In order to produce autogenous ignition the temperature of the heated surface in contact with the vapor-air mixture must be high enough to cause the initial reactions to become autogenous or self-supporting. It is assumed that the heat generated during the initial stages of the reactions under the conditions of the test must exceed the heat dissipation, resulting in acceleration of the initial processes and rise in temperature of the mixture.

The temperature of the mixture[1] at the instant of ignition, that is, appearance of flame, may be considerably above the temperature of the heated surface. It would be difficult to measure either the temperature of the mixture during the initial stages or at the instant of ignition, but the initial temperature of the heated surface causing the ignition can be measured, as is done in the present method.

The ignition temperature of a liquid of the exothermic class depends in a measure upon the proportions of vapor in air in the test mixture. That mixture of any vapor in air having the lowest ignition temperature is the one in which we are interested. It is not necessary in this method of test to predetermine the proportions of vapor in air that will give the minimum ignition temperature. In these tests various proportions of vapor in air were brought into contact with the heated surface. It is easy in one trial test to have too little vapor and in the next too much vapor to give the mixture that will ignite at the lowest temperature; hence, it may be necessary to conduct a large number of tests with any liquid to obtain the minimum ignition temperature.

Proposed Revisions:

It is recommended that various minor revisions be made in the Tentative Method of Test for the Determination of Autogenous Ignition Temperatures (D 286 - 28 T) as outlined in the report[2] of Committee D-2, and that the method as revised be advanced to standard.

Future Work:

It is recommended that an additional series of cooperative tests at different laboratories be conducted using the method as revised.

Respectfully submitted on behalf of the subcommittee,

A. H. NUCKOLLS,
Chairman.

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[1] The mixture at this stage consists largely of intermediate products.

[2] See p. 776.—ED.

REPORT OF COMMITTEE D-4
ON
ROAD AND PAVING MATERIALS

This year Committee D-4 recommends the revision of one tentative specification, the revision of one standard method of test without publication as a tentative revision and the advancement to standard of nine tentative specifications, three of them with minor revisions.

Upon its recommendation, as the Sectional Committee on Methods of Testing Road and Paving Materials functioning under the procedure of the American Standards Association, the following five standard methods have been advanced from the status of American Tentative Standards to American Standards:

Standard Method of Test for Toughness of Rock (D 3 - 18) (A. S. A. No. A 5 - 1930);
Standard Method of Test for the Determination of Bitumen (D 4 - 27) (A. S. A. No. A 37c - 1930);
Standard Method of Test for Penetration of Bituminous Materials (D 5 - 25) (A. S. A. No. A 37a - 1930);
Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (D 75 - 22) (A. S. A. No. A 26 - 1930);
Standard Method of Float Test for Bituminous Materials (D 139 - 27) (A. S. A. No. A 37b - 1930).

The committee has reviewed the proposed revised report of the Conference Committee, composed of representatives of Committee D-2 on Petroleum Products and Lubricants, Committee D-8 on Bituminous Waterproofing and Roofing Materials and Committee D-4, dealing with definitions of the terms bitumens, asphalts, tars, pitches and fluxes, and has formally approved that report.

During the past year the Section on Distillation has carried on exhaustive investigations with the object of developing a suitable method for use in the distillation of cut-back asphalts. While not at the present time ready to recommend a definite method until further investigations have been conducted, Committee D-4 nevertheless believes that the work already accomplished is of sufficient value to warrant publication of the report of the section, which is accordingly appended hereto.

There are a number of tentative standards under the jurisdiction of the committee which have been tentative for three years or more without revision. These tentative specifications: namely, D 99 - 26 T, D 100 - 26 T, D 101 - 26 T, D 102 - 24 T, D 103 - 24 T, D 133 - 23 T, D 134 - 23 T, D 135 - 23 T, D 163 - 23 T, D 164 - 23 T, D 241 - 26 T and D 242 - 26 T, all cover asphalt products. It is felt that while these specifications are not sufficiently complete to be advanced to standard they should be continued as tentative to serve as a guide to the highway engineer. This matter is being studied by the Section on Asphalt Specifications which feels that at almost any time a satisfactory solution may be found.

The Tentative Method of Test for Ductility of Bituminous Materials (D 113 - 26 T) is still the subject of criticism to which the section having jurisdiction over the test method is giving due consideration but is not yet prepared to offer a revision or recommend that the method be advanced to standard. It is accordingly recommended that this method be continued as tentative.

The committee recommends that the Tentative Specifications for Commercial Sizes of Broken Stone and Broken Slag for Highway Construction (D 63 - 23 T) and for Commercial Sizes of Sand and Gravel for Highway Construction (D 64 - 20 T) be continued as tentative. It is felt that neither of these specifications merit advancement to standard for several reasons. In the first place, the question of the proper shape of opening in laboratory screens has not been settled and it is felt that it would be unwise to standardize the commercial sizes in terms of round openings with the possibility that square openings will later become a standard. It is also felt that the Society should not standardize commercial sizes without an agreement on the part of all interests concerned. It would seem that such an agreement cannot be reached through the small representation in Committee D-4 and that this problem should be handled by the Division of Simplified Practice of the U. S. Department of Commerce.

The tentative revisions[1] of the Standard Specifications for Broken Slag for Waterbound Base and Wearing Course (D 65 - 23) and for Shovel-Run or Crusher-Run Broken Slag for Waterbound Base (D 66 - 23) recommend the omission of the abrasion test for slag when used either as a base course or as a surface course. It is believed that more data are necessary before these revisions should be adopted and the committee recommends that they be continued as tentative.

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[1] *Proceedings*, Am. Soc. Terting Mats., Vol. 29, Part I, pp. **866**, **867** (**1929**); also 1929 Book of A.S.T.M. Tentative Standards, pp. 820, 821.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Proposed Revision of Tentative Specifications:

Tentative Specifications for Calcium Chloride for Dust Prevention (D 98 – 22 T).[1]—In order to meet justifiable criticisms which have been received, the committee recommends that these specifications be revised as follows and continued as tentative:

Section 2.—Change the first paragraph to read as follows by the omission of the words in brackets:

2. The calcium chloride shall be in the form of loose dry lumps or flakes, [and fine enough to feed readily through the common forms of spreaders used in road work,] and when tested by means of laboratory screens and sieves shall conform to the following requirements:

Section 3.—Change to read as follows by the omission of the words in brackets:

3. [Ten grams of the material dissolved in 100 cc. of boiling water shall show less than 1.0 per cent insoluble residue. Not more than 1.0 cc. of normal acid shall be required to neutralize the alkalinity of the filtrate, using methyl orange.] The chemical composition shall conform to the following requirements:

$CaCl_2$ (anhydrous)	not less than	73	per cent
$MgCl_2$	not more than	0.5	"
NaCl	not more than	2.0	"
Other impurities	not more than	1.0	"

[The percentage of calcium chloride shall be calculated from the peercntage of calcium in the filtrate above referred to, after making a deduction for the SO_4, which shall be assumed to be in combination as $CaSO_4$.]

Section 4.—Change the first sentence to read as follows by the addition of the italicized figures and the omission of the words and figures in brackets:

4. The calcium chloride shall be delivered in [air-tight] moisture-proof bags or sacks containing approximately 100 lb. each, or in air-tight steel drums weighing not more than [350] *450* lb. each.

Section 7.—Omit this section reading as follows:

7. Payment will be made on the basis of total number of pounds of 100-percent calcium chloride delivered.

Proposed Revision of Standard Methods:

Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 – 27).[2]—In order to increase the accuracy of this test by a more definite and detailed description of the apparatus the following revisions are recommended. This proposed revision constitutes no radical change in method but merely increases its accuracy, and it is accordingly recommended that it be incorporated in the present standard without publication as a tentative revision. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 790 (1922); also 1929 Book of A.S.T.M. Tentative Standards, p. 428.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 489.

Section 2.—Change from its present form: namely,

2. The oven may be either circular or rectangular in form and may be heated by either gas or electricity. Its interior dimensions shall be as follows: height, not less than 40.64 cm. (16 in.); width and depth or diameter, at least 5.08 cm. (2 in.) greater than the diameter of the revolving shelf.

It shall be well ventilated and shall be fitted with a window in the upper half of the door, so placed and of sufficient size to permit the accurate reading of the thermometer without opening the door. It shall also be provided with a perforated circular shelf preferably of approximately 24.8 cm. (9.75 in.) in diameter. This shelf shall be placed in the center of the oven and shall be suspended by a vertical shaft and provided with mechanical means for rotating it at the rate of 5 to 6 revolutions per minute. It shall be provided with recesses equidistant from the central shaft in which the tins containing the samples are to be placed. (A recommended form of aluminum shelf is shown in Fig. 1.)

to read as follows:

2. The oven shall be rectangular in form with double walls and heated by electricity. Its interior dimensions shall be as follows: height, exclusive of space occupied by the heating element, not less than 29.26 cm. (11.5 in.), width and depth, each, at least 5.08 cm. (2 in.) greater than the diameter of the revolving shelf.

The oven shall be provided with a perforated metal circular shelf approximately 24.8 cm. (9.75 in.) in diameter. A recommended form of aluminum shelf is shown in Fig. 1. This shelf shall be placed in the center of the oven, with respect to all dimensions of the interior of the same, suspended by a vertical shaft and provided with mechanical means for rotating it at the rate of 5 to 6 revolutions per minute.

One side of the oven shall be hinged and equipped to serve as a tight fitting door which shall contain a window at least 4 in. square, with double glass, through which a thermometer, located in front of and level with the revolving shelf, may be read without opening the door.

One round vent hole each shall be placed in the top and bottom of the oven or one only near the top and one only near the bottom on each side of the oven. Each hole shall be not less than 1.27 cm. ($\frac{1}{2}$ in.) nor more than 1.60 cm. ($\frac{5}{8}$ in.) in diameter and they shall both be left open during the operation of the oven.

Section 4.—Change to read as follows by the addition of the italicized words and the omission of those in brackets:

4. The container in which the sample is to be tested shall be of [tin] *metal or glass,* cylindrical in shape, and shall have a flat bottom. Its inside dimensions shall be substantially as follows: diameter 55 mm. (2.17 in.); depth 35 mm. (1.38 in.). (A 3-oz. Gill style *flat-bottom, seamless* ointment box, deep pattern, fulfills these requirements.).

Section 6.—Change to read as follows, by the addition of the italicized words and the omission of the words and figures in brackets:

6. Fifty grams of the water-free material to be tested shall be weighed into a tared container conforming to the requirements of Section 4. The oven shall be brought to a temperature of 163° C. (325° F.) and the [tin] box containing the sample placed in one of the recesses of the revolving shelf. [The thermometer shall be immersed for the depth of its bulb in a separate 50-g. sample of the material under test, placed in a similar container, and shall be conveniently suspended from the vertical shaft. This sample shall rest in one of the recesses upon the same shelf and revolve with the sample or samples under test.] The oven shall then be closed and the shelf rotated 5 to 6 revolutions per minute during the entire test. The temperature shall be maintained at 163° C. (325° F.) for 5 hours, *after the sample has been introduced and the oven has again reached that temperature.* [then the] *The* sample shall be removed from the oven, cooled and weighed, and the loss due to volatilization calculated.

Note.—Change the note at the end of the method to read as follows by the addition of the italicized words and the omission of those in brackets:

NOTE.—If additional periods of heating *or other temperatures* are desired, it is recommended that they be made in successive increments of 5 hours each.

When the penetration *or other characteristics* of the sample after heating [is] *are* required, melt the residue in the container at the lowest possible temperature and thoroughly mix by stirring, taking care to avoid incorporating air bubbles in the mass. Then bring it to the standard temperature and test as prescribed [under the directions for] *in* the Standard Method of Test for Penetration of Bituminous Materials (A.S.T.M. Designation: D 5) of the American Society for Testing Materials, *or such other standard conditions as may be required by other test procedure involved.*

Advancement of Tentative Standards to Standard:

Tentative Specifications for High-Carbon Tar for Surface Treatment, Cold Application (D 104 - 27 T).[1]—In order to make these specifications more generally applicable and bring them up to date, the committee recommends that this tentative standard be revised as follows and advanced to standard:

Section 1 (d).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

(d) Specific gravity at 25° C. (77° F.) of total distillate
to 300° C. (572° F.)....................not less than [1.01] *1.00*

Section 2 (b).—Change the first sentence to read as follows by the addition of the italicized figures and the omission of those in brackets:

(*b*) Specific Viscosity: Method contained in Bulletin No. [691] *1216*, U. S. Department of Agriculture, the instrument being standardized by the *U. S.* Bureau of Standards.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 936, (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 450.

Tentative Specifications for Low-Carbon Tar for Surface Treatment, Cold Application (D 105 - 27 T).[1]—In order to bring these specifications up to date the committee recommends that this tentative standard be revised as follows and advanced to standard:

Section 2 (b).—Change the first sentence to read as follows by the addition of the italicized figures and the omission of those in brackets:

(*b*) Specific Viscosity: Method contained in Bulletin No. [691] *1216,* U. S. Department of Agriculture, the instrument being standardized by the *U. S.* Bureau of Standards.

Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 28 T).[2]—In order to make the specified dimensions of the distillation flask more practicable of application without in any way changing the apparatus or method of test the following revision is recommended. The committee also recommends that this tentative method, as revised, be advanced to standard:

Section 2.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

2. Flask.—The distillation flask, Fig. 1, shall be a side neck distilling flask, having the following dimensions:

Diameter of bulb, outside	86	mm.	± 1.5 mm.
Diameter of neck, inside	22	mm.	± 1.0 mm.
Diameter of tubulature, inside	10	mm.	± 0.5 mm.
[Length of neck	43	mm.	± 1.0 mm.]
Height of flask, outside	*131*	*mm.*	± *1.5 mm.*
[Distance, top of neck to tubulature	25	mm.	± 1.0 mm.]
Vertical distance bottom of bulb, outside, to horizontal tangent at tubulature inside	*93*	*mm.*	± 1.5 *mm.*
Length of tubulature	220	mm.	± 5.0 mm.
Angle of tubulature	73	deg.	± [1] *2* deg.
Thickness of tubulature wall	*1.0 to 1.5 mm.*		

Figure 1 —Change to comply with the revised method of expressing dimensions.

No criticisms having been received in the following tentative specifications, the committee recommends that they be advanced to standard:

Tentative Specifications for High-Carbon Tar for Surface Treatment, Hot Application (D 108 - 27 T);[3]

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 27, Part I, p. 938 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 452.

[2] *Proceedings,* Am. Soc. Testing Mats., Vol. 28, Part I, p. 943 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 476.

[3] *Proceedings,* Am. Soc. Testing Mats., Vol. 27, Part I, p. 944 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 458.

Tentative Specifications for Low-Carbon Tar for Surface Treatment, Hot Application (D 109 – 27 T);[1]

Tentative Specifications for High-Carbon Tar Cement (D 110 – 27 T);[1]

Tentative Specifications for Low-Carbon Tar Cement (D 111 – 27 T);[1]

Tentative Specifications for Coal-Tar Pitch for Stone Block Filler (D 112 – 27 T);[1]

Tentative Specifications for Gravel for Bituminous Concrete Base (D 309 – 29 T).[2]

The election of officers resulted in the selection of the following: P. J. Freeman, chairman; H. L. Howe, first vice-chairman; A. T. Goldbeck, second vice-chairman; C. S. Reeve, third vice-chairman, and Prévost Hubbard, secretary.

The results of letter ballot of the committee upon the recommendations made in this report appear in the following table:

Items	Affirmative	Negative	Not Voting
I. Proposed Revision of Existing Tentative Standard			
Tentative Specifications for Calcium Chloride for Dust Prevention (D 98 – 22 T)	39	1	43
II. Proposed Revision of Standard			
Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 – 27), immediate adoption	43	0	40
III. Proposed Advancement of Tentative Standards to Standard			
Tentative Specifications for High-Carbon Tar for Surface Treatment, Cold Application (D 104 – 27 T), as revised	35	0	48
Tentative Specifications for Low-Carbon Tar for Surface Treatment, Cold Application (D 105 – 27 T), as revised	35	0	48
Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 28 T), as revised	43	0	40
Tentative Specifications for High-Carbon Tar for Surface Treatment, Hot Application (D 108 – 27 T)	36	0	47
Tentative Specifications for Low-Carbon Tar for Surface Treatment, Hot Application (D 109 – 27 T)	36	0	47
Tentative Specifications for High-Carbon Tar Cement (D 110 – 27 T)	35	0	48
Tentative Specifications for Low-Carbon Tar Cement (D 111 – 27 T)	35	0	48
Tentative Specifications for Coal-Tar Pitch for Stone Block Filler (D 112 – 27 T)	34	1	48
Tentative Specifications for Gravel for Bituminous Concrete Base (D 309 – 29 T)	36	0	47

This report has been submitted to letter ballot of the committee, which consists of 83 members; 50 members returned their ballots, of whom 39 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

R. W. Crum,
Chairman.

Prévost Hubbard,
Secretary.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, pp. 946–952 (1927); also 1929 Book of A.S.T.M. Tentative Standards, pp. 460–466.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 702 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 422.

EDITORIAL NOTE

The proposed revision of the Tentative Specifications for Calcium Chloride for Dust Prevention was accepted. The specifications in their revised form appear on page 1145.

The proposed immediate revision of the Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds was approved at the annual meeting by a unanimous vote and was subsequently adopted by letter ballot of the Society on September 2, 1930. The standard method in its revised form appears in the 1930 Book of A.S.T.M. Standards, Part II, page 638.

The Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment, as revised; the Tentative Specifications for High-Carbon Tar for Surface Treatment, Cold Application, as revised; for Low-Carbon Tar for Surface Treatment, Cold Application, as revised; for High-Carbon Tar for Surface Treatment, Hot Application; for Low-Carbon Tar for Surface Treatment, Hot Application; for High-Carbon Tar Cement; for Low-Carbon Tar Cement; for Coal-Tar Pitch for Stone Block Filler; and for Gravel for Bituminous Concrete Base were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standards appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 642, 595, 597, 599, 601, 603, 605, 607 and 574, respectively.

APPENDIX

REPORT ON COOPERATIVE WORK ON THE SEPARATION OF CUT-BACK ASPHALT

During the past four years a special committee of the Distillation Section of Committee D-4 has been working on methods for the separation of cutback asphalts so that the amount and character of both the base and the cutback could be determined. Various types of distillation equipment have been used. The following table indicates the progress that has been made in this work:

	Original Penetration of Base	Variation in Penetration of Recovered Base	Average Variation in Penetration
Series No. 1	60	60 to 129	89
Series No. 2	50	44 to 107	70
Series No. 3	50	Hard to 114	89
Present Series, method A	56	57 to 99	78
Present Series, method B	56	45 to 90	63

It was felt that sufficient progress had been made to justify the publication of the results of the present series of tests. Two methods were employed on five samples of materials and eleven laboratories reported results.

The first method known as method A is an atmospheric distillation using the present Tentative Method of Distillation of Bituminous Materials Suitable for Road Treatment (D 20 - 28 T)[1] with the bulb of the thermometer ½ in. from the bottom of the flask. The distillation is continued until the thermometer indicates 680° F. This method was developed by Mr. S. A. Montgomery of the Standard Oil Company of Indiana.

The second method known as method B starts with an atmospheric distillation and completes the distillation in a vacuum not exceeding 10 mm. of mercury. This method was developed in the Laboratory of the Tennessee State Highway Department.

The data reported by the cooperators included the specific gravity, and the Furol and Engler viscosities of the original material, the percentages of base and cut-back, the penetration of the base and the distillation of the cut-back. These data are given in Table I for

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 943 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 476.

TABLE I.—RESULTS OF SEPARATION OF CUT-BACK ASPHALT.

	Standard	Laboratory											Average
		No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10	No. 11	
SAMPLE NO. 1, METHOD A													
Specific Gravity Sample at 77° F	...	0.940	...	...	0.940	...	0.938	...	0.939	0.939	...	0.938	0.939
Furol Viscosity at 122° F	72	76	80	71	78	76	81	...	83	78	...	80	78
Engler Specific Viscosity at 104° F	..	37.8	...	...	38.2	36.5	34.8	...	36.6	35.3	39.4	35.3	36.9
Distillation of Sample:													
Oil off to 437° F., per cent	..	20.0	22.0	20.0	21.5	21.5	21.5	21.0	20.0	19.8	19.8	20.5	20.7
Oil off to 600° F., per cent	..	31.0	31.5	32.0	32.5	32.5	32.5	33.1	32.3	32.0	32.0	32.5	32.2
Oil off to 680° F., per cent	..	33.0	34.5	34.0	34.5	34.3	34.4	35.0	34.5	34.6	34.5	35.0	34.4
Percentage of Cut-back	35	33.0	34.5	34.0	34.5	34.3	34.4	35.0	34.5	34.6	34.5	35.0	34.4
Percentage of Base (by difference)	65	67.0	65.5	66.0	65.5	65.7	65.6	65.0	65.5	65.4	65.5	65.0	65.6
Penetration of Base at 77° F	56	57	85	89	75	74	81	70	85	71	66	99	78
Distillation of Cut-back:													
Initial boiling point, deg. Fahr	306	307	305	307	306	306	306	280	309	...	...	305	304
10 per cent point, deg. Fahr	326	322	320	324	324	322	322	320	...	...	...	323	322
50 per cent point, deg. Fahr	344	345	340	340	343	341	340	342	...	...	...	345	342
90 per cent point, deg. Fahr	386	383	375	372	375	372	372	372	...	...	...	380	375
End point, deg. Fahr	408	410	415	428	422	398	425	400	417	...	...	425	416
A.P.I. Gravity	48	48.6	...	...	38.2	48.5	...	...	49.5	...	...	...	46.2
SAMPLE NO. 1, METHOD B													
Percentage of Cut-back	35	32.0	34.0	34.8	34.9	34.2	28.4	35.9	28.4	35.9	34.8	35.3	33.5
Percentage of Base (by difference)	65	68.0	66.0	65.2	65.1	65.8	71.6	64.1	71.6	64.1	65.2	64.7	66.5
Penetration of Base at 77° F	56	90	50	57	62	76	83	59	206*	48	45	58	63
Distillation of Cut-back:													
Initial boiling point, deg. Fahr	306	309	311	313	300	306	312	306	290	304	...	311	306
10 per cent point, deg. Fahr	326	329	324	326	320	322	322	324	...	325	...	325	326
50 per cent point, deg. Fahr	344	345	342	343	340	342	340	342	...	345	...	345	343
90 per cent point, deg. Fahr	386	371	374	377	376	372	371	374	...	381	...	381	375
End point, deg. Fahr	408	401	411	415	404	410	421	416	409	412	...	420	412
A.P.I. Gravity	48	49.5	...	...	48.1	48.1	...	...	49.7	49.7	...	...	49.0
SAMPLE NO. 3, METHOD A													
Specific Gravity Sample at 77° F	...	0.948	...	...	0.945	...	0.948	...	0.949	0.951	...	0.947	0.948
Furol Viscosity at 122° F	79	90	85	77	85	85	87	...	85	83	...	85	85
Engler Specific Viscosity at 104° F	...	48.6	...	...	40.5	39.5	37.9	...	39.6	39.7	41.3	38.3	40.7
Distillation of Sample:													
Oil off to 437° F., per cent	...	0.0	0.0	0.0	Trace	0.0	0.0	0.0	0.0	1.5	0.0	0.3	0.0
Oil off to 600° F., per cent	...	27.0	27.5	27.0	26.5	27.0	27.4	27.3	26.5	26.9	27.0	27.0	27.0
Oil off to 680° F., per cent	...	32.0	31.0	34.0	31.5	31.5	31.5	31.9	32.0	31.9	31.8	32.0	31.9
Percentage of Cut-back	35	32.0	31.0	34.0	31.5	31.5	31.5	31.9	32.0	31.9	31.8	32.0	31.9
Percentage of Base (by difference)	65	68.0	69.0	66.0	68.5	68.5	68.5	68.1	68.0	68.1	68.2	68.0	68.1
Penetration of Base at 77° F	115	125	Soft	210	186	196	192	175	239	209	225	258	201
Distillation of Cut-back:													
Initial boiling point, deg. Fahr	362	370	360	360	365	364	362	360	360	...	...	370	363
10 per cent point, deg. Fahr	392	389	392	393	394	390	390	386	...	...	...	397	391
50 per cent point, deg. Fahr	428	426	424	421	424	424	421	420	...	...	...	427	423
90 per cent point, deg. Fahr	474	486	480	469	469	470	468	466	...	...	...	481	474
End point, deg. Fahr	516	518	514	518	533	494	519	494	480	...	...	503	508
A.P.I. Gravity	41.4	42.5	...	...	41.9	42.3	...	...	42.8	...	...	...	42.4
SAMPLE NO. 3, METHOD B													
Percentage of Cut-back	35	33.3	34.0	34.2	33.8	33.1	27.3	35.3	19.3	35.0	34.0	33.8	32.1
Percentage of Base (by difference)	65	66.7	66.0	65.8	66.2	66.9	72.7	64.7	80.7	65.0	66.0	66.2	67.9
Penetration of Base at 77° F	115	82	117	105	156	235	271	119	Soft	108	100	114	140
Distillation of Cut-back:													
Initial boiling point, deg. Fahr	362	379	372	370	368	368	368	374	...	356	...	369	369
10 per cent point, deg. Fahr	392	401	401	396	396	396	391	396	...	397	...	398	397
50 per cent point, deg. Fahr	428	432	430	426	426	427	420	426	...	432	...	430	428
90 per cent point, deg. Fahr	474	476	478	482	470	478	463	474	...	477	...	482	476
End point, deg. Fahr	516	503	516	541	514	500	510	534	...	520	...	520	518
A.P.I.Gravity	41.4	37.9	...	...	41.4	42.0	...	...	48.8	41.3	...	...	42.3

two of the samples, Nos. 1 and 3, that cover commercial grades of materials.

Results from the following laboratories are reported:

No. 1. W. H. Fulweiler, The United Gas Improvement Co., Philadelphia, Pa.
No. 2. H. K. Buckner, Dept. of Highways, Nashville, Tenn.
No. 3. F. C. Read, Standard Oil Co. of Louisiana, Baton Rouge, La.
No. 4. M. H. Ulman, Pennsylvania Dept. of Highways, Harrisburg, Pa.
No. 5. F. S. Dengler, The Texas Co., Port Neches, Tex.
No. 6. P. D. Miesenhelder, Indiana State Highway Commission, Indianapolis, Ind.
No. 7. S. A. Montgomery, Standard Oil Co. of Indiana, Wood River, Ill.
No. 8. R. B. Gage, New Jersey State Highway Commission, Trenton, N. J.
No. 9. A. S. Rea, Ohio Dept. of Highways, Columbus, Ohio.
No. 10. W. F. Purrington, New Hampshire State Highway Dept., Concord, N. H.
No. 11. E. O. Rhodes, American Tar Products Co., Pittsburgh, Pa.

It will be noted that both methods give close approximations to the percentages of cut-back and base and that there was slightly less variation in the penetrations observed in method A, but that the average of method B was somewhat closer to the true penetration than that observed in method A. It should be borne in mind that vacuum distillation involves technique which is not normally employed in a road testing laboratory so that it is quite possible that more experience with method B would yield considerably better results. In this connection attention should be called to the results obtained by laboratories Nos. 2 and 3 as these laboratories have used the vacuum method regularly.

The principal criticism of the vacuum method in addition to the more complicated apparatus was the considerably increased amount of time required to secure results.

As might be expected, a number of details involved in the technique of carrying out both methods will require study. Among these may be mentioned the necessity of immediately removing the residue from the distillation flask in connection with method A and in securing closer control over the vacuum used in method B, the vacuums used by the collaborators varying from 4 to 63 mm. while the method calls for a vacuum of less than 10 mm.

The work will be continued, and in addition to the two methods used in the present series a modification of the atmospheric method suggested by Mr. M. H. Ulman will be tried. This involves a short steam distillation after the atmospheric distillation is finished.

Respectfully submitted on behalf of the special committee,

W. H. FULWEILER,
Chairman.

REPORT OF COMMITTEE D-5
ON
COAL AND COKE

Committee D-5 on Coal and Coke held one meeting during the past year at Detroit, Mich., on March 18, and another will be held at the annual meeting of the Society prior to the presentation of this report.

ACTIVITIES OF SUBCOMMITTEES

Subcommittee I on Methods of Testing (A. C. Fieldner, chairman). —This subcommittee conducted an investigation of a commercial form of the micro-pyrometer apparatus for the determination of the fusibility of coal ash. Nineteen coal ashes, covering a wide range in ash fusibility as determined by the standard gas-furnace method, were sent to five laboratories equipped with the micro-pyrometer apparatus for check determinations of ash fusibility. Fusibility determinations were made on the ashes by the standard gas-furnace method at the Pittsburgh station of the U. S. Bureau of Mines. The different laboratories using the micro-pyrometer method did not check one another in determining ash fusibility on the same ash. In general, the micro-pyrometer results showed considerable variation from the standard gas-furnace results. The results of the investigation have been published in detail by the U. S. Bureau of Mines.[1]

A plan of locating sampling points for collecting samples of anthracite from tops of loaded cars for size testing has been submitted by the Anthracite Bureau of Information with the suggestion that it replace the method now specified in the Tentative Method of Test for Size of Anthracite (D 310 - 29 T). The advantage claimed for this plan is that the sampling points are staggered to conform to the distribution of the coal as loaded. This location of sampling points is worthy of consideration by the committee and, for information, is illustrated in Fig. 1. The Tentative Method of Test for Size of Anthracite (D 310 - 29 T) is to be continued as tentative pending a decision on the best method for collecting samples from tops of loaded cars.

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[1] W. A. Selvig, "Check Determinations of Fusibility of Coal Ash with the De Graaf Electric Coal-Ash Fusion Furnace," U. S. Bureau of Mines, *Reports of Investigations*, Serial No. 3003 (1930).

Subcommittee II on Nomenclature and Definitions (H. C. Porter, chairman).—This subcommittee is submitting revisions of the Tentative Definitions of Terms Relating to Coal and Coke (D 121 – 27 T) as given below and recommends that the definitions, as revised, be advanced to standard. The revised definitions have been approved by Committee E-8 on Nomenclature and Definitions. The definition of the term coke is being continued as tentative.

Subcommittee VIII on Foundry Coke Specifications (J. T. MacKenzie, chairman).—This subcommittee prepared a proposed system of tolerances for foundry coke so as to recognize the different grades now on the market. To obtain criticisms the system of tolerances was published in the *A.S.T.M. Bulletin*, No. 38, April 30, 1929, and was also sent to a large number of producers and consumers of foundry coke. The subcommittee has accumulated considerable valuable information but is not ready to recommend a revision of the present Standard Specifications for Foundry Coke (D 17 – 16).

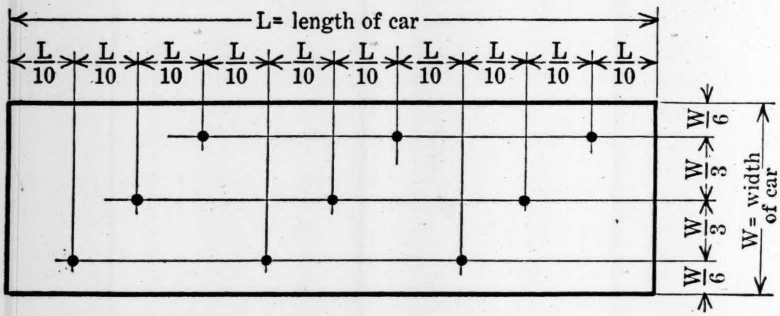

FIG. 1.—Location of Sampling Points for Nine-Point Sample from Top of Car.

Subcommittee IX on Coke Sampling (O. O. Malleis, chairman).—This subcommittee has prepared a method of sampling coke which is appended hereto as information. Criticisms of this method are solicited.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Advancement of Tentative Standards to Standard:

Tentative Method of Test for Fineness of Powdered Coal (D 197 – 26 T).[1]—This method has been continued as tentative for a number of years pending investigations as to methods of collecting samples in unit powdered coal systems. However, no practical methods have been developed better than the one given in the tentative standard and the committee recommends that the method be advanced to standard, without revision.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 898 (1926); also 1929 Book of A.S.T.M. Tentative Standards, p. 502.

Tentative Method of Test for Sieve Analysis of Crushed Bituminous Coal (D 311 – 29 T).[1]—The committee recommends that this method be advanced to standard without revision.

Tentative Definitions of Terms Relating to Coal and Coke (D 121 – 27 T).[2]—This tentative standard contains definitions of the terms coke, beehive coke, by-product coke, coke breeze, and dry coke. The committee recommends that the definitions, for beehive coke, by-product coke, coke breeze and dry coke, with the definitions for the terms by-product coke, and dry coke revised as follows, be advanced to standard and added to the present standard Definitions of Terms Relating to Coal and Coke (D 121 – 27):

By-Product Coke.—Change the definition of this term to read as follows by the omission of the words in brackets:

> *By-Product Coke.*—Coke manufactured with attendant recovery of by-products, in ovens that are heated externally [and having properties making it available for metallurgical purposes].

Dry Coke.—Change the definition of this term from its present form: namely,

> *Dry Coke.*—Coke which has been dried to constant weight at temperatures not less than 104° C. nor more than 200° C. in the case of lump coke, and between 104 and 110° C. in the case of coke passing a No. 60 sieve in accordance with methods of determining moisture prescribed in the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials.

to read as follows:

> *Dry Coke.*—A laboratory term applied to coke which has been dried to constant weight in accordance with definite prescribed methods.
>
> NOTE.—The methods employed shall be those for the determination of moisture prescribed in the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials. In the case of lump coke, the temperature shall be not less than 104° C. nor more than 200° C.; in the case of coke passing a 250-micron (No. 60) sieve, the temperature shall be not less than 104° C. nor more than 110° C. for a period of 1 hour.

Advancement to Standard of Tentative Revision of Standard:

Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 29).[3]—The committee recommends that the tentative revision of this standard method published last year[4] be adopted as standard. This revision consists of (*a*) a revision in the fusion point of pure K_2CrO_4, changing the temperature 940° C. to 968° C., (*b*) a revision in the temperature of igniting coal and coke with Eschka mixture, changing the range 870 – 925° C. to 800° ± 25° C. and (*c*) a revision of the requirements for the calorimeter bomb in the calorimetric determination.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 711 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 510.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 962 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 512.

[3] 1929 Supplement to Book of A.S.T.M. Standards, p. 212.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 871 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 825.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

Results of the letter ballot of the committee concerning the recommendations made in this report are given in the following table:

Items	Affirmative	Negative	Not Voting
I. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
Tentative Method of Test for Fineness of Powdered Coal (D 197 – 26 T).............	31	2	12
Tentative Method of Test for Sieve Analysis of Crushed Bituminous Coal (D 311 – 29 T)	34	0	11
Tentative Definitions of Terms Relating to Coal and Coke (D 121 – 27 T)............	34	0	11
II. ADVANCEMENT TO STANDARD OF TENTATIVE REVISION OF STANDARD			
Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (D 271 – 29).	34	0	11

This report has been submitted to letter ballot of the committee, which consists of 45 members; 36 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

A. C. FIELDNER,
Chairman.

W. A. SELVIG,
Secretary.

H. C. PORTER,
Vice-Chairman.

EDITORIAL NOTE

The Tentative Methods of Test for Fineness of Powdered Coal and for Sieve Analysis of Crushed Bituminous Coal were approved at the annual meeting and were subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 727 and 732, respectively.

The definitions of the terms "by-product coke," and "dry coke," as revised; and the terms "coke breeze," and "beehive coke"; appearing in the Tentative Definitions of Terms Relating to Coal and Coke were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The definitions as approved appear in the 1930 Book of A.S.T.M. Standards, Part II, page 752.

The tentative revision of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standard methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 689.

APPENDIX

PROPOSED METHOD OF SAMPLING COKE[1]

In general, the sampling procedure outlined in the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21 – 16) of the American Society for Testing Materials[2] has been followed in preparing this method of sampling coke. The main deviation is in the reduction in the weight of the gross sample, coke is generally made from mixed pulverized coal or coals and therefore is a fairly uniform product. In the case of coke made from coarsely crushed or uncrushed coal, a larger gross sample is specified.

It is imperative that every sample be collected and prepared carefully and conscientiously and in strict accordance with the standard procedure described herein, for if the sampling is improperly done, the sample will be in error, and it may be impossible or impracticable to take another sample; but if an analysis is in error, another analysis can easily be made of the original sample.

Gross samples of the quantities designated herein must be taken whether the coke to be sampled consists of a few tons or several hundred tons in order to minimize the effect of the chance inclusion or exclusion of too many or too few pieces of non-representative material.

FOR ALL DETERMINATIONS EXCEPT TOTAL MOISTURE

1. *Time of Sampling.*—(*a*) The coke shall preferably be sampled when it is being loaded into or unloaded from railroad cars, ships, barges, or trucks, or when discharged from supply bins, or railroad cars or grab buckets, or from any coke-conveying equipment, as the case may be.

(*b*) Samples collected from the surface of coke in piles or bins, or in cars, ships or barges may be unreliable. Often, however, it is necessary or very desirable to collect such a sample and the following points should be kept in mind.

> (*1*) For run-of-oven coke and coke 2 in. and larger in size containing breeze, samples collected from the surface of loaded shipments would generally be unreliable because of segregation.
>
> (*2*) For shipments of coke which are loaded from "bottom to top," as in the case of barges, samples collected from the surface of loaded shipments would not necessarily be representative of the coke below the surface and therefore would be unreliable.
>
> (*3*) For shipments of coke free of breeze, which are loaded from "end to end" so that the coke on top should be similar to the coke below the surface, as in case of open-top railroad cars, samples collected from the surface of loaded shipments should be fairly representative.

In case it is necessary to collect a sample from coke exposed in bins or cars, care should be taken to take coke pieces representing the entire exposed area. This is best accomplished by dividing the exposed surface to be sampled into a number of approximately equal areas, and selecting equal increments from each area.

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[1] **Criticisms of this proposed method are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.**

[2] **1927 Book of A.S.T.M. Standards, Part II, p. 530.**

2. *Size of Increments.*—To collect samples, a shovel or specially designed tool or mechanical means shall be used for taking equal portions or increments. For coke smaller than about 2 in., increments as small as 1 to 2 lb. may be taken, but for coke larger than about 2 in., increments should be at least 2 to 5 lbs.

3. *Collection of Gross Sample.*—The increments shall be regularly and systematically collected, so that the entire quantity of coke sampled will be represented proportionately in the gross sample, and with such frequency that a gross sample of the required amount shall be collected. The standard gross sample shall not be less than 250 lb. for cokes made from finely pulverized coal (about 60 per cent passing a ⅛-in. sieve) and not less than 500 lb. for cokes made from coarsely crushed or uncrushed coal except that for breeze coke, a gross sample of approximately 125 lb. shall be considered sufficient.

4. *Quantity Represented.*—A gross sample shall be taken for each 250 tons or fraction thereof.

5. *Crushing.*—After the gross sample has been collected, it shall be systematically crushed, mixed, and reduced in quantity to convenient size for transmission to the laboratory. The sample shall preferably be crushed by means of a jaw or roll crusher, or in case mechanical crushing means are not available, the coke sample may be crushed on a chilled iron or hard steel plate by impact of a tamper, hard bar or sledge, avoiding all rubbing action, as otherwise the ash content will be materially increased by the addition of iron from the sampling apparatus, even though hardened iron or steel is used. The crushing shall be done under such conditions as shall prevent loss of coke or accidental admixture of foreign matter. Samples of the quantities indicated in Table I shall be crushed so that no pieces of coke and impurities will be greater in dimension, as judged by eye, than specified for the sample before division into two approximately equal parts:

TABLE I.—WEIGHTS OF COKE SAMPLES WITH CORRESPONDING CRUSHING SIZES.

WEIGHT OF SAMPLE TO BE REDUCED, LB.	LARGEST SIZE OF COKE AND IMPURITIES ALLOWABLE IN SAMPLE BEFORE REDUCTION
250 or over	1 in.
125	½ in.
60	¼ in.
30	3/16 in. or to pass a 4760-micron (No. 4) sieve

The method of reducing by hand the quantity of coke in a gross sample shall be carried out as described in Section 6, even should the initial size of coke and impurities be less than indicated in Table I.

6. *Mixing and Reduction.*—The progressive reduction in the weight of the sample to the quantities indicated in Table I shall be done by the following methods which are described and illustrated in Plate V of the Standard Method of Sampling Coal (A.S.T.M. Designation: D 21 – 16) of the American Society for Testing Materials.[1]

(*a*) The alternate-shovel method of reducing the gross sample shall be repeated until the sample is reduced to approximately 125 lb., and care shall be observed before each reduction in quantity that the sample has been crushed to the fineness specified in Table I.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 530.

(*b*) After the gross sample has been reduced by the alternate-shovel method to approximately 125 lb., further reduction in quantity shall be by the quartering method. Before each quartering, the sample shall be crushed to the fineness specified in Table I.

(*c*) The 30-lb. quantity shall be crushed to $\frac{3}{16}$-in. size or to pass a 4760-micron (No. 4) sieve, mixed, coned, flattened and quartered. The laboratory samples shall include all of one of the quarters, or all of two opposite quarters, as may be required. The laboratory sample shall be immediately placed in a suitable container and sealed in such a manner as to preclude tampering.

7. *Reduction by Mechanical Means.*—Only such mechanical means as will give equally representative samples shall be used in substitution for the hand method of reduction in quantity herein standardized.

FOR THE DETERMINATION OF TOTAL MOISTURE

8. *Sample for Total Moisture.*—For determining total moisture, a special moisture sample weighing approximately 50 lb., except in the case of breeze coke, in which case the moisture sample shall weigh approximately 25 lb., shall be taken. The sample shall be accumulated by placing in a waterproof receptacle with a tight-fitting and waterproof lid small equal parts of the freshly-taken increments of the standard gross sample described in Section 2. The special moisture sample, without any preliminary crushing, should preferably be dried in accordance with Section 5 (*a*) of the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271 - 29). In case it is impracticable to dry the entire sample, the following procedures may be used:

FOR COKE APPEARING DRY.—The special moisture sample shall be rapidly crushed and reduced mechanically or by hand to about a 5-lb. quantity, which shall be immediately placed in a container and sealed airtight and forwarded to the laboratory without delay.

FOR COKE APPEARING WET.—The special moisture sample shall be spread on tared pans, weighed, and air-dried or dried in a warm place or on a warm or heated surface until the coke appears dry, and weighed again. The sampling shall be completed as described in the preceding paragraph for coke appearing dry. This loss in weight divided by weight of sample times 100 is the percentage air-drying loss and should be corrected as follows for the moisture found in the sample sent to the laboratory:

$$\text{Percentage Total Moisture (as received)} = \frac{100 - \text{percentage of air-drying loss}}{100}$$

$$\times \text{ percentage moisture in air-dried sample} + \text{percentage of air-drying loss.}$$

9. *Use of Standard Sample.*—Only when equally representative results will be obtained shall the standard gross sample be used instead of the special moisture sample for the determination of total moisture.

10. *Report.*—In the report of the analysis, a brief description should be given of the method of taking the sample, by such characteristic expressions as "Belt Sample," "Top-of-car," etc. Information as to how the sample is taken should be included in the description which accompanies the sample sent to the laboratory for inclusion in the report of analyses.

REPORT OF SECTIONAL COMMITTEE
ON
CLASSIFICATION OF COALS

During the past year the Sectional Committee on Classification of Coal has continued to collect facts and data on the composition and properties of North American coals with reference to scientific and use classification. Although no formal reports have yet been submitted by any of the technical committees or their subcommittees, all of them have been active, and individual members have presented their work in a series of papers at a symposium on the classification of coal held at the February, 1930, meeting of the American Institute of Mining and Metallurgical Engineers. These papers and the discussions will be published by the Institute, thus making the information available in convenient form for use in the development of systems of classification.

The Associate Committee on Coal Classification of the National Research Council of Canada has likewise pursued an active program and has sponsored the publication of two important papers[1] on the classification of Canadian coals.

Close contact is being maintained with the Canadian committee by interchange of reports and attendance of representatives at meetings. The chairman attended the annual meeting of the Canadian committee at Edmonton, Alta., on October 8, 1929, and several members of the Canadian committee have attended the meetings of the sectional committee.

The three technical committees of the sectional committee held two group meetings during the year, one in Philadelphia, on November 21 and 22, 1929, and the other in New York City, at the time of the annual meeting of the sectional committee on March 27, 1930. Subcommittee I on Nature, Location and Mode of Occurrence of Types of American Coals met in Washington, D. C., on March 26, 1930.

At the March annual meeting all the officers of the sectional and technical committees were reelected for two years with the exception of the secretary, Mr Harry L. Gandy, whose resignation was tendered because of his resignation as Executive Secretary of the National Coal Association. In accepting Mr. Gandy's resignation the committee expressed its deep appreciation of the valuable help which he has given the committee since its organization Mr. C. B. Huntress, who succeeded Mr. Gandy as Executive Secretary of the National Coal Association, was elected secretary. Other changes in committee personnel in the past year were the loss of Mr. Samuel B. Crowell by death and the loss of Mr. W. B. Calkins by resignation. The National Retail Coal Association has named Mr. Charles B. Johnson, President, George B. Newton Coal Co., Philadelphia, Pa., to succeed Mr. Crowell, and the committee elected Mr. Charles O'Neill, Vice-President of Peale, Peacock and Kerr, Inc., to succeed Mr. Calkins.

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[1] E. Stansfield and J. W. Sutherland, "The Classification of Canadian Coals," *Canadian Mining and Metallurgical Bulletin No. 210*, 1929, p. 1158.

R. E. Gilmore, "Status of Coal Classification in Canada," Am. Inst. Mining and Metallurgical Engrs. Preprint, Classification of Coal, 1930, pp. 27–38.

Technical Committee on Use Classification:

The Technical Committee on Use Classification continued the collection of data on the different uses for coal and the requirements for these uses. Reports have been published on railroad fuel,[1] steam coal[2] and coal for gas and coke production.[3] Data are now being assembled on coal used in the ceramic, the metallurgical, the cement, and the coking industries.

Technical Committee on Marketing Practice:

The Technical Committee on Marketing Practice has practically completed its program of collecting information on marketing practice with reference to classes of coal in the various marketing areas of the country. These reports have been mimeographed and distributed to all members of the sectional committee, and three of them[4] have been published in the American Institute of Mining and Metallurgical Engineers symposia on coal classification.

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[1] E. McAuliffe and M. Macfarlane, "Classification of Coals from the Point of View of the Railroads," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication 156*, 1928, pp. 75–80.

Malcolm Macfarlane, "Selection and Use of Fuels in Locomotive Practice," *Transactions*, Am. Soc. Mechanical Engrs., Vol. 50, No. 33, pp. 157–60 (1928).

[2] S. B. Flagg, "Classification of Coal from the Standpoint of the Steam Power Consumer," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication 156*, 1928, pp. 91–94.

[3] W. H. Fulweiler, "The Use Classification of Coal as Applied to the Gas Industry," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, 1928, pp. 81–86.

Gilbert Francklyn, "Properties of Coal Which Affect Its Use for the Manufacture of Coal Gas, Water Gas and Producer Gas," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 140–146.

[4] F. R. Wadleigh, "Commercial Classification of Coal," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, 1928, pp. 73–74; Preprint, Classification of Coal, 1930, pp. 107–132.

F. G. Tryon, "Classification of Coal from the Standpoint of the Coal Statistician," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, 1928, pp. 95–99.

E. W. Parker, "Commercial Description of Pennsylvania Anthracite," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 133–139.

Technical Committee on Scientific Classification:

The Technical Committee on Scientific Classification, through its various subcommittees, has made considerable progress in correlating existing systems of classification and in laying down broad lines on which coal may be classified on the basis of its intrinsic physical and chemical properties. A tentative agreement has been reached to use the term "rank" to describe the progressive change of coal in the transformation from peat to anthracite, and the term "type" to designate the character of a coal as conditioned by the original vegetable matter from which it is derived. It was also agreed to divide coal into certain groups and classes approximately as follows:

Group	Class
Brown Coal	*A*. Peat *B*. Brown Coal *C*. Lignite
Sub-bituminous	Two or three classes
Bituminous	Three or four classes
Anthracite	*A*. High Volatile *B*. Low Volatile *C*. Meta-anthracite

Although no definite action has yet been taken, the majority of the committee favor classifying coal in the condition "as mined," namely, the "mine-moisture" is considered part of the coal.

Subcommittee I on Nature, Location, and Mode of Occurrence of Types of American Coals has made considerable progress in outlining the natural groups[1] of coal and allied fuels and in suggesting certain fundamentals in coal classification.[2] Tentative agreement has been reached by the subcommittee on the following:

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[1] M. R. Campbell, "Natural Groups of Coal and Allied Fuels," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 6–21.

[2] C. A. Seyler, "The Classification of Coal," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, 1928, pp. 4–14.

W. T. Thom, Jr., "Classification of Coal from Proximate Analysis and Calorific Value," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, pp. 15–19.

H. J. Rose, "Classification of Coals by Ultimate Analysis," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, pp. 20–24.

M. R. Campbell, "Classification of Coal from the Viewpoint of the Geologist," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, pp. 25–27.

R. Thiessen, "Classification of Coal from the Viewpoint of the Paleobotanist," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, pp. 28–46.

W. Francis, "Classification of Coal in the Light of Recent Discoveries with Regard to Its Constitution," Am. Inst. Mining and Metallurgical Engrs., *Technical Publication No. 156*, pp. 47–67.

Geo. H. Ashley, "Coal Classification: A Review and Forecast," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 22–26.

David White, "Outline of a Suggested Classification of Coals," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal.

R. E. Gilmore, "Status of Coal Classification in Canada," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, pp. 27–38.

1. The degree of metamorphism shall be the primary factor in the scientific classification of coal.

2. Subdivisions shall be made into four and five groups of classes, with the lignite or brown coal group at the low end of the scale of rank and an anthracitic group at the high end of the scale.

3. The low group may be called the brown coal group and will comprise three classes, namely, peat, (German) brown coal, and lignite.

4. The high group may be called the anthracite group and will comprise three classes, namely, high volatile as represented by Bernice anthracite; low volatile, the normal Pennsylvania anthracite; and the Rhode Island type of graphites.

5. There shall be two groups of classes between the brown coal and anthracite groups.

Further study of analyses and results of slacking and friability tests is needed before deciding on the number of classes in each of the two intermediate groups. Such studies are now in progress at the Geological Survey and Bureau of Mines Stations of the United States and Canadian governments.

Subcommittee II on Methods of Analysis, Origin, and Composition of Coal has reviewed the methods used in coal analysis and has estimated probable variations in analytical results that may be expected from different analysts working on samples of the same coal. The effect on results of modifications in methods of analysis is discussed also in the same report.[1]

The question of whether to use the simple "uncorrected-ash" analytical values in coal classification, or the corrected values as suggested by Parr or others[2] is undecided.

The subcommittee has given much time to collecting data on this question and has published a report discussing various correction formulas and their application.[3] Stansfield and Sutherland of the Canadian committee have presented data on determining the ratio of ash to mineral matter in a coal by fractionating the coal with heavy solutions,[4] and Turner[5] has shown that most of the mineral matter of coal can be removed by acid treatment. However, the subcommittee is not convinced that the acid treatment does not affect the coal substance. Further experimental work is in progress on this and other methods of avoiding or minimizing the "ash-correction" error.

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[1] A. C. Fieldner, "Review of Methods Used in Coal Analysis with Particular Reference to Classification of Coal," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 39–50.

[2] F. V. Tideswell and R. V. Wheeler, "Pure Coal as a Basis for Classification," *Technical Publication No. 104*, Am. Inst. Mining and Metallurgical Engrs., 1928.

[3] A. C. Fieldner and W. A. Selvig, "Present Status of Ash Corrections in Coal Analysis," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 51–65.

[4] E. Stansfield and J. W. Sutherland, "Determination of Mineral Matter in Coal and Fractionating Studies of Coal," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 66–78.

[5] H. G. Turner, "Constitution and Nature of Pennsylvania Anthracite with Comparisons to Bituminous Coal," Am. Inst. Mining and Metallurgical Engrs., Preprint, 1930.

The slacking and friability investigation at the Bureau of Mines laboratories has continued throughout the year. Such tests have been made on samples from all the mines of the State of Washington. In this list are included all ranks of coal from lignite to anthracite. Samples have been taken also in several other coal fields in order to cover various types of coal. Both slacking and friability tests give promise of being useful in the classification of coal according to rank. Work on classification according to type is getting under way. Mr. Reinhardt Thiessen of the Bureau of Mines has contributed a preliminary report on splint coal[1] and is making microscopic studies of the Pittsburgh, Elkhorn, and Taggert Beds of the Appalachian coal field. These coals represent attrital, anthraxylal, and splinty coals, three important types of coal from the standpoint of origin.

Subcommittee III on Present and Proposed Systems of Classification has developed the Rose multibasic coal chart[2] for comparing graphically various systems for classifying coals. This chart greatly facilitates such comparisons, on the basis of any desired analytical or test figures, and any purity basis. It is expected that the committee will employ a full-time investigator to chart and study the accumulating data with respect to the most promising systems for classification. The work of the committee has reached the stage where it requires the undivided attention of at least one man to keep the work going toward a successful conclusion.

Respectfully submitted on behalf of the sectional committee,

A. C. FIELDNER,
Chairman.

C. B. HUNTRESS,
Secretary.

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[1] Reinhardt Thiessen, "Splint Coal," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930, pp. 79–106.

[2] H. J. Rose, "The Multibasic Coal Chart," Am. Inst. Mining and Metallurgical Engrs., Preprint, Classification of Coal, 1930.

REPORT OF COMMITTEE D-7
ON
TIMBER

Committee D-7 on Timber, through its various subcommittees has done considerable work during the past year, and reports the following detailed activities of these subcommittees:

Subcommittee I on Specifications for Timber (C. E. Paul, chairman).—This subcommittee has developed new Proposed Tentative Specifications for Timber Piles, appended hereto,[1] which the subcommittee recommends be issued as a tentative standard to supersede when adopted the present Standard Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted (D 25 - 20).[2] It is accordingly recommended that the Standard Specifications D 25 be withdrawn.

The subcommittee has carefully considered the tentative revision of the Standard Specifications for Wood Joist, Planks, Beams, Stringers and Posts (D 245 - 27) proposed last year and now recommends that this revision be advanced to standard. The specifications in their revised form are appended hereto.[3]

Subcommittee VI on Timber Preservatives (S. R. Church, chairman).—This subcommittee has worked very closely in cooperation with committees of the American Wood Preservers' Association and the American Railway Engineering Association and presents a number of changes in the standards under its jurisdiction as given in detail in the report of the subcommittee appended hereto.

The subcommittee recommends that the Proposed Tentative Definitions of Terms Relating to Timber Preservatives, appended hereto,[4] be accepted for publication as tentative.

The subcommittee recommends that the procedure for specific gravity of fractions described in Sections 11 to 15 of the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 - 27)[5] be withdrawn and a reference incorporated in the standard methods to the Proposed Tentative Method for the Determination of the Specific Gravity 38°/15.5° C. of Creosote Fractions, appended hereto.[6] The committee accordingly asks for the necessary nine-tenths vote for the immediate revision of Standard D 38. The committee also recommends that the proposed method appended hereto be published as tentative to be incorporated, when adopted, in the Standard Methods D 38.

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[1] See p. 1148.—Ed.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 623.

[3] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 754.—Ed.

[4] See p. 1154.—Ed.

[5] 1927 Book of A.S.T.M. Standards, Part II, p 683.

[6] See p. 1152.—Ed.

As a result of cooperation with the American Wood Preservers' Association the subcommittee recommends for immediate adoption a complete revision of the Standard Method of Test for Coke Residue of Creosote Oil (D 168 – 27).[1] The method in its revised form is appended hereto.[2] The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

The subcommittee is also recommending a revision for immediate adoption, in its report appended hereto, in the Standard Method of Test for Distillation of Creosote Oil (D 246 – 28).[3] The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Subcommittee X on Nomenclature and Definitions (C. J. Hogue, chairman).—After careful consideration of the Tentative Definitions of Terms Relating to Timber (D 9 – 29 T)[4] the committee recommends that these tentative definitions of terms with certain minor editorial changes to bring them in line with the recommendations of Committee E-8 on Nomenclature and Definintions be adopted as standard.

Subcommittee XI on Moisture Content of Timber (M. E. Dunlap, chairman).—This subcommittee has continued its investigations and presents a progress report appended hereto as information.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED TENTATIVE STANDARDS			
Definitions of Terms Relating to Timber Preservatives	19	0	1
Method for the Determination of the Specific Gravity, 38°/15.5° C. of Creosote Fractions	18	0	2
Specifications for Timber Piles	20	0	0
II. PROPOSED REVISION OF STANDARDS			
Methods of Sampling and Analysis of Creosote Oil (D 38 – 27), immediate revision	17	0	3
Method of Test for Coke Residue of Creosote Oil (D 168 – 27), immediate adoption	17	0	3
Standard Method of Test for Distillation of Creosote Oil (D 246–28), immediate adoption	19	0	1
III. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Definitions of Terms Relating to Timber (D 9 – 29 T)	19	0	1
IV. ADVANCEMENT TO STANDARD OF TENTATIVE REVISIONS OF STANDARD			
Specifications for Structural Wood Joist, Planks, Beams, Stringers and Posts (D 245 – 27)	19	0	1
V. WITHDRAWAL OF STANDARD			
Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted (D 25 – 20)	20	0	0

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 692.

[2] The revised methods were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 882.—ED.

[3] 1928 Supplement to Book of A.S.T.M. Standards, p. 163.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 713 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 513.

This report has been submitted to letter ballot of the committee which consists of 26 members; 20 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

HERMANN VON SCHRENK,
Chairman.

J. A. NEWLIN,
Secretary.

EDITORIAL NOTE

The proposed Tentative Definitions of Terms Relating to Timber Preservatives and the proposed Tentative Method for the Determination of the Specific Gravity, 38°/15.5° C., of Creosote Fractions were accepted for publication as tentative as were also the proposed Specifications for Timber Piles to supersede the present Standard Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted. The tentative standards appear on pages 1154, 1152 and 1148, respectively. The withdrawal of the Standard Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted was accordingly approved.

The proposed immediate revision of the Standard Methods of Sampling and Analysis of Creosote Oil; of the Standard Methods of Test for Coke Residue of Creosote Oil and for Distillation of Creosote Oil was approved at the annual meeting by a unanimous vote and subsequently adopted by letter ballot of the Society on September 2, 1930. The standard methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 874, 882 and 885, respectively.

The Tentative Definitions of Terms Relating to Timber, to supersede the present Standard Definitions of Terms Relating to Structural Timber, were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, page 894.

The tentative revision of the Standard Specifications for Structural Wood Joist, Planks, Beams, Stringers and Posts was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, page 754.

REPORT OF SUBCOMMITTEE VI ON TIMBER PRESERVATIVES

In the 1928 and 1929 reports[1] of Subcommittee VI the work at the U. S. Bureau of Standards on density and volume-temperature corrections for creosote oil has been reported upon and working tables have been made available.

At the request of a joint conference committee in charge of this work the Bureau undertook to make similar determinations on representative samples of coke oven tars. The report of the Bureau on this work is shown in Table I.

This subcommittee has recommended that the joint conference committee request the Bureau to prepare tables for various creosote coal-tar solutions, from 80 per cent creosote and 20 per cent coal-tar to 50 per cent creosote and 50 per cent coal-tar.

New Tentative Standard.—The American Railway Engineering Association has adopted a number of definitions for terms used in wood preservation.[2] The most important of these is the definition for creosote or creosote oil. The need for a definition of this term for specific use in the wood-preserving industry has been increasingly felt. The only definition available for this specific use, that of the American Wood Preservers' Association, has been generally held to be inadequate. The subcommittee has prepared Proposed Tentative Definitions of Terms Relating to Timber Preservatives, appended hereto[3] which are recommended as tentative. The definitions have been prepared as the result of a long series of correspondence among a number of qualified authorities representing the American Railway Engineering Association, the American Wood Preservers' Association and the American Society for Testing Materials. The definitions for creosote coal-tar solution and for creosote distillate are subsidiary and the tar definitions are for the purpose of showing the sources of tar from which creosote may be obtained.

Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 27)[4]:

As a result of cooperation with the Preservatives Committee of the American Wood Preservers' Association the subcommittee recommends that the procedure for specific gravity of fractions described in Sections 11 to 15 of Methods D 38 – 27 be withdrawn since neither of the two methods described in the present standard is in popular use. A survey has revealed that a large majority of analysts favor and are using the pycnometer method.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vols. 28 and 29, respectively, Part I, pp. 549 and 408 (1928 and 1929).

[2] *Bulletin No. 321*, Vol. 31, November, 1929, p. 665.

[3] See p. 1154.—Ed.

[4] 1927 Book of A.S.T.M. Standards, Part II, p. 683.

The subcommittee accordingly recommends that the Proposed Tentative Method for the Determination of the Specific Gravity, 38°/15.5° C., of Creosote Fractions, appended hereto,[1] be accepted for publication as tentative to be incorporated, when adopted, in the Standard Methods D 38. Until the proposed method is made part of the standard methods the subcommittee recommends that a reference to the proposed procedure be incorporated in the standard methods. The proposed method is in accordance with the method recommended by the Preservatives Committee of the American Wood Preservers' Association.

TABLE I.—REPORT ON THE DENSITY AND THERMAL EXPANSION OF COKE-OVEN TARS.

Temperature Range, deg. Cent.	No. 1,[a] Density 1.1387 g. per ml. at 40° C.	No. 2,[a] Density 1.1685 g. per ml. at 40° C.	No. 3,[a] Density 1.1334 g. per ml. at 40° C.	No. 4,[a] Density 1.1749 g. per ml. at 40° C.	2835-P,[b] Density 1.1475 g. per ml. at 40° C.	2836-P,[b] Density 1.1694 g. per ml. at 40° C.	2837-P,[b] Density 1.1784 g. per ml. at 40° C.
AVERAGE RATE OF CHANGE IN VOLUME PER UNIT VOLUME PER DEGREE CENTIGRADE CHANGE IN TEMPERATURE							
40 to 50.........	0.00063	0.00059	0.00063	0.00057	0.00062	0.00060	0.00059
50 to 60.........	0.00063	0.00059	0.00063	0.00058	0.00063	0.00060	0.00059
60 to 70.........	0.00064	0.00060	0.00064	0.00059	0.00064	0.00061	0.00060
70 to 80.........	0.00064	0.00060	0.00065	0.00060	0.00064	0.00062	0.00060
80 to 90.........	[c]	0.00061	0.00068	0.00061	0.00064	0.00062	0.00061
AVERAGE RATE OF CHANGE IN DENSITY[d] PER DEGREE CENTIGRADE CHANGE IN TEMPERATURE							
40 to 50.........	0.00071	0.00069	0.00071	0.00067	0.00070	0.00069	0.00069
50 to 60.........	0.00071	0.00069	0.00071	0.00067	0.00070	0.00069	0.00069
60 to 70.........	0.00073	0.00069	0.00072	0.00068	0.00071	0.00070	0.00069
70 to 80.........	0.00073	0.00070	0.00072	0.00069	0.00072	0.00070	0.00070
80 to 90.........	....	0.00070	0.00074	0.00070	0.00072	0.00071	0.00070

[a] Sample furnished by Barrett Co.

[b] Samples furnished by American Tar Products Co.

[c] Sample No. 1 developed gas in the pycnometer at approximately 80° C.; therefore, no observations from 80° to 90° C.

[d] Density values are reported in grams per milliliter.

The subcommittee also recommends that the tentative revision proposed last year[2] in the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 27) be continued as tentative.

Standard Method of Test for Coke Residue of Creosote Oil (D 168 – 27)[3]:

The subcommittee recommends that this standard method be completely revised as appended hereto.[4] This revision consists in specifying an orifice of definite size in the crucible lid in place of the indefinite "crease," and in controlling more closely the temperature of the crucible during the test. The revised procedure is in accordance with the method of the Committee on Preservatives of the A.W.P.A. The subcommittee recommends that the method as revised be continued as standard and accordingly asks for the necessary nine-tenths vote for immediate adoption.

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[1] See p. 1152.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 872 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 826.

[3] 1927 Book of A.S.T.M. Standards, Part II, p. 692.

[4] The revised methods were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 882.—ED.

Standard Method of Test for Distillation of Creosote Oil (D 246 – 28)[1]*:*

In order to make the specified dimensions of the distillation flask more practicable of application without in any way changing the apparatus or method of test the following revision is recommended. This change is recommended by Committee D-4 on Road and Paving Materials as the result of observation that it is impossible to determine accurately the 25-mm. dimension now specified as the distance from the top of the flask to the top of the intake. The subcommittee recommends that this revision be adopted immediately and the method continued as standard. The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Section 2.—Change to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

2. Flask.—The distillation flask, Fig. 1, shall be a side neck distilling flask, having the following dimensions:

Diameter of bulb, outside	86 mm. ± 1.5 mm.
Diameter of neck, inside	22 mm. ± 1.0 mm.
Diameter of tubulature, inside	10 mm. ± 0.5 mm.
[Length of neck	43 mm. ± 1.0 mm.]
Height of flask, outside	*131 mm. ± 1.5 mm.*
[Distance, top of neck to tubulature	25 mm. ± 1.0 mm.]
Vertical distance bottom of bulb, outside, to horizontal tangent at tubulature inside	*93 mm. ± 1.5 mm.*
Length of tubulature	220 mm. ± 5.0 mm.
Angle of tubulature	73 deg. ± [1] *2* deg.
Thickness of tubulature wall	*1.0 to 1.5 mm.*

Figure 1.—Change to comply with the revised method of expressing dimensions.

The subcommittee is now considering the revision and enlargement of the procedure for sampling of creosote oil described in the Standard Methods of Sampling and Analysis of Creosote Oil (D 38 – 27). The details of the distillation procedure described in this standard method are also being investigated.

Respectfully submitted on behalf of the subcommittee,

S. R. CHURCH,
Chairman.

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[1] **1928 Supplement to Book of A.S.T.M. Standards, p. 163.**

REPORT OF SUBCOMMITTEE XI ON MOISTURE CONTENT OF TIMBER

Since the preparation of the last report of this subcommittee rather satisfactory progress has been made in the field of rapid moisture indicating apparatus. One electrical device shown in Fig. 1 has been manufactured and distributed to the woodworking industry by the C. J. Tagliabue Co. This instrument measures the electrical resistance of wood, contact with which is made by two pairs of points driven into the wood. The result is expressed in terms of moisture content instead of actual resistance. The instrument may be used either for the determination of moisture content or it may be used to sort lumber above and below a desired moisture content. The latter feature is accomplished by the flashing of a green light when the moisture content is too high.

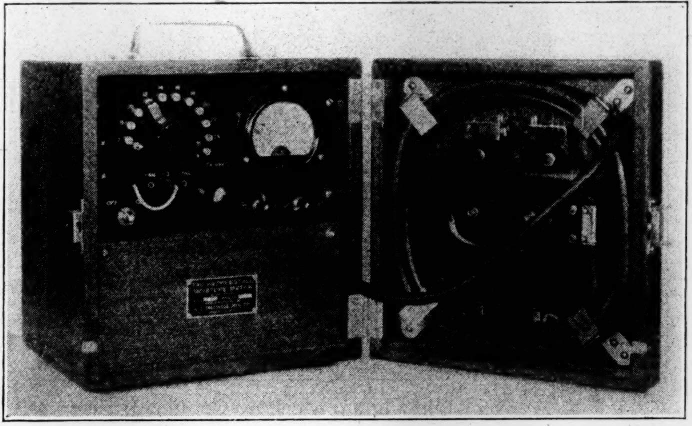

FIG. 1.—Tag-Heppenstall Moisture Meter.

The U. S. Forest Products Laboratory at Madison, Wis., has done some further work in the development of instruments and has worked on several different types. Outstanding among these instruments is a simple resistance type of apparatus utilizing two neon glow lamps combined in a circuit with the wood and a group of condensers in such a way that the flashes of the test lamp can be synchronized by switching in the proper size condensers with a standard lamp which flashes at the rate of 60 per minute. The instrument can be used for sorting lumber for a maximum moisture content or for moisture content determination. A new type of electrode has been developed for use with this instrument, patterned after a hammer with the points set in the faces so that they may be easily driven into the wood. A photograph of this apparatus is shown in Fig. 2. This instrument may be used for moisture contents between 7 and 8 per cent to 26 per cent and may be made to read higher than this percentage by lowering the voltage or the introduction of larger condensers.

Some experimental work has been done on other electrical circuits but they have not reached a stage of development to know their practical value.

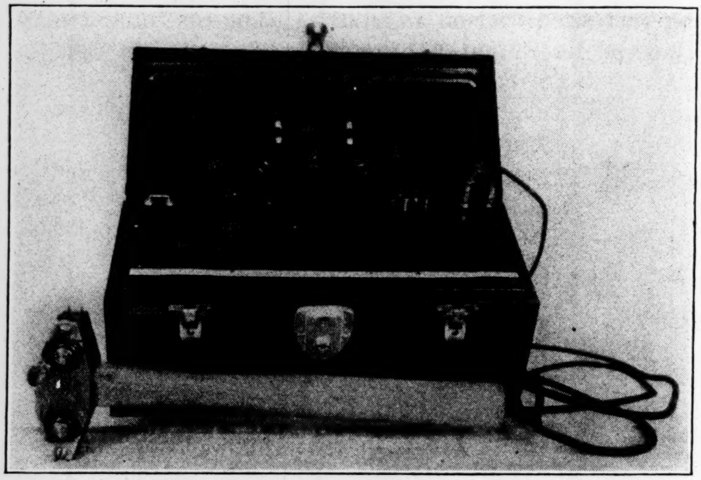

FIG. 2.—Neon Glow-Lamp Moisture Content Indicator.

The electrical resistance of different woods has been studied to some extent and has brought out the fact that the electrical resistances of woods vary considerably so that an instrument cannot be used indiscriminately on different species and corrections must be provided for accurate work.

It should be pointed out further that the calibrations of instruments have been based on well-conditioned samples and that it may be expected that wood when freshly kiln dried will not be uniform in moisture content and that variations in results may be expected. Some judgment and experience will probably be required for instruments thus far developed.

A further progressive step as an aid in the development of moisture-indicating instruments was made at the U. S. Forest Products Laboratory during the year in the conditioning of wood samples. This

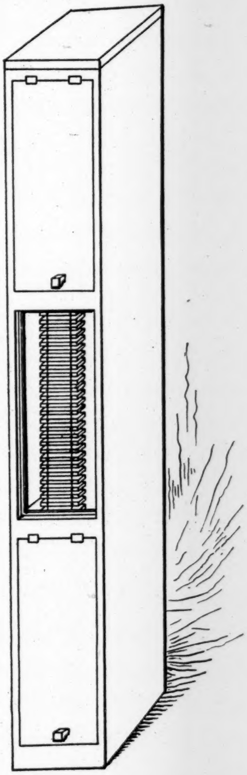

FIG. 3.—Wood Sample Conditioning Tower.

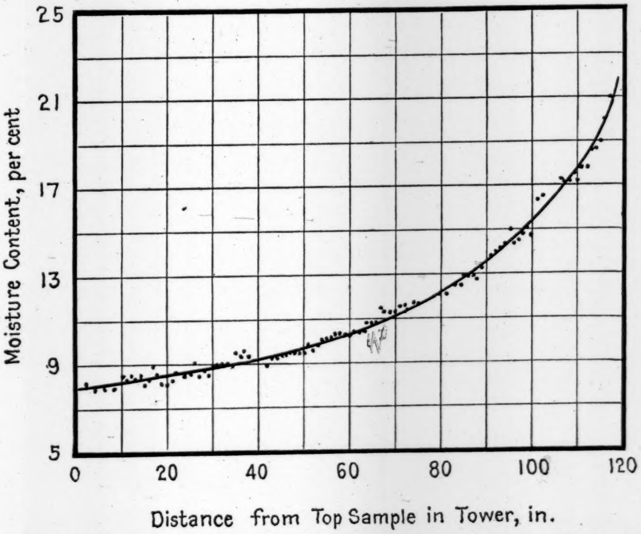

FIG. 4.—Moisture Content Distribution of Samples of Douglas Fir in Wood Conditioning Tower.

method enables an investigator to obtain a sequence of moisture contents differing by only a few tenths of 1 per cent, completely covering the range of moisture contents necessary for calibration.

In a heated room or compartment in which the air is practically still there exists an appreciable gradient in temperature between the floor and ceiling. For instance, in a room 10 ft. in height as much as 16° F. difference between floor and ceiling will be found at normal temperatures. Then if the air is saturated at the floor level the relative humidity at the ceiling will amount to approximately 60 per cent and this may be lowered still further by the introduction of a heat source at the ceiling or top of the compartment.

To accomplish this result a tower as shown in Fig. 3 has been built in which a series of samples can be placed and allowed to stand until moisture conditions in the wood have become approximately uniform, when they may be used for calibration purposes. Figure 4 illustrates the moisture content arrangement of samples of Douglas fir according to height in the tower. This tower was not supplied by an independent source of heat at the top.

Respectfully submitted on behalf of the subcommittee,

M. E. DUNLAP,
Chairman.

REPORT OF COMMITTEE D-8
ON
BITUMINOUS WATERPROOFING AND ROOFING MATERIALS

During the past year Committee D-8 on Bituminous Waterproofing and Roofing Materials has created two new subcommittees, namely, Subcommittee VIII on Accelerated Weathering Tests under the chairmanship of Mr. O. G. Strieter, and Subcommittee IX on Bituminous Emulsions under the chairmanship of Mr. Edgar S. Ross.

The committee has endeavored to balance its personnel in strict accordance with the Regulations Governing Standing Committees but has been unable to secure a sufficient number of individual non-producers to equal its present producer membership. So far as voting strength is concerned, however, the situation has been remedied by combining the letter ballots of all individual members connected with any single organization.

As the result of requests from various sources, the committee has considered it advisable to define the terms "waterproofing" and "damp-proofing." It has, therefore, prepared the following proposed definitions which, by letter ballot of the committee, have been referred to Committee E-8 on Nomenclature and Definitions:

Waterproofing.—A means intended to prevent ingress or egress of water where it accumulates under pressure.

Damp-proofing.—A means intended to resist the ingress of moisture where it cannot accumulate under pressure.

RECOMMENDATIONS AFFECTING STANDARDS

Advancement of Tentative Standard to Standard.—No criticisms having been received of the Tentative Specifications for Acid-Resisting Asphalt Mastic (D 223 – 25 T),[1] the committee feels that they are in satisfactory form. It is therefore recommended that these tentative specifications be advanced to standard.

Withdrawal of Standard and Reversion to Tentative Standard.—During the year considerable progress has been made in completely revising the Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules (D 228 - 27)[1] in order to make them more generally applicable and to meet certain criticisms that have been received. While it has not been possible to complete this revision in time for presentation at the annual meeting, Committee D-8 feels that the existing methods should be withdrawn as a standard in view of their probable early revision. It is recommended, therefore, that this standard be withdrawn and published as a tentative standard.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 759 (1925); also 1929 Book of A.S.T.M. Tentative Standards, p. 537.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

The results of the letter ballot of the committee upon the recommendations made in this report are given in the following table:

Items	Affirmative	Negative	Not Voting
I. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Tentative Specifications for Acid-Resisting Asphalt Mastic (D 223 - 25 T)...........	35	0	8
II. PROPOSED WITHDRAWAL OF STANDARD AND REVERSION TO TENTATIVE STANDARD			
Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules (D 228 - 27)..........	31	2	10

This report has been submitted to letter ballot of the committee, which consists of 43 voting members; 36 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

S. T. WAGNER,
Chairman.

PRÉVOST HUBBARD,
Secretary.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 778.

EDITORIAL NOTE

The Tentative Specifications for Acid-Resisting Asphalt Mastic were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, page 922.

The proposed withdrawal of the Standard Methods of Testing Asphalt Roll-Roofing Surfaced with Fine Talc, Granular Talc, or Mineral Granules, Likewise Asphalt Shingles Surfaced with Mineral Granules as a standard method of the Society and the publication of these methods as a tentative standard was approved. The tentative methods appear on page 1155.

REPORT OF COMMITTEE D-9
ON
ELECTRICAL INSULATING MATERIALS

Two meetings, each of two days' duration, have been held by the committee and its subcommittees during the year. The meetings held were as follows:

At Keystone Athletic Club., Pittsburgh, Pa, October 24 and 25, 1929;

At Larchmont Yacht Club, Larchmont, N. Y., March 27 and 28, 1930.

A third meeting will be held at Atlantic City, N. J., at the annual meeting of the Society previous to the presentation of this report.

The subcommittees have found it to their advantage to hold additional meetings at times other than those at which the main committee held its meetings. Subcommittee III on Sheet Insulation has been most active in this regard during the past year.

The committee has been active in the development of new methods of testing insulating materials; in the improvement of the present standard or tentative standard methods; and in the preliminary drafting of specifications. The scope of the work is covered in detail in the following recommendations affecting methods of test and in the description of the activities of the subcommittees.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

Proposed Tentative Method of Test for Comparing the Thermal Conductivities of Solid Electrical Insulating Materials:

For several years the committee has been interested in trying to work out a test for measuring the thermal conductivity of insulating materials. The flat plate method has always been considered as satisfactory in the insulating trades, but it was felt that a simpler method could be worked out. This involved the development of materials which could be considered as standards of thermal conductivity. The U. S. Bureau of Standards has developed a series of samples of rubber containing different percentages of graphite which seem to meet the requirements for a standard. After a long series of tests consisting of comparisons among different laboratories the committee has finally come to definite recommendations in regard to a method of measuring thermal conductivity. It is therefore recommended that the proposed Tentative Method of Test for Comparing the Thermal Conductivities of Solid Electrical Insulating Materials, appended hereto,[1] be accepted for publication as tentative.

Standard Methods of Testing Molded Insulating Materials (D 48 – 29):[2]

The continuation of tests on water absorption confirmed the opinion that the recommendation made last year[3] relative to the change in the form of the test specimen was a wise one and consequently the committee recommends that the tentative revision of Section 23 be adopted as standard. The section as revised reads as follows:

> 23. The test specimen shall be molded in the form of a disk 4 in. (10.16 cm.) in diameter which should be ⅛ in. (3.18 mm.) in thickness for hot-molded materials, and ¼ in. (6.35 mm.) in thickness for cold-molded materials.

In connection with the illustrations of all test specimens in Methods D 48 – 29, it has been decided that it is advisable to specify certain tolerances, depending upon the type of material to be used. It is, therefore, recommended that the following note be added to Figs. 1, and 3 showing the test specimens and also that this note be included in Sections 7 and 15 which describes the compression and dielectric strength test specimens, and also in the revised Section 23 which describes the water absorption specimen:

> NOTE.—To permit the use of one mold for all molding compounds the following variations in dimensions of the test specimen will be permissible:

For hot molding compounds....................	± 5 per cent
For cold molding compounds..................	± 10 per cent

Standard Methods of Testing Electrical Insulating Oils (D 117 – 27):[4]

Continued study of methods of sampling electrical insulating oils has brought out certain minor changes in the present tentative revision of these methods, issued last year,[5] which the committee recommends be approved and the revision as revised continued as tentative for another year:

Section 3.—Change Paragraph (*a*) to read as follows by the addition of the italicized words:

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[1] See p. 1224.—ED.

[2] 1929 Supplement to Book of A.S.T.M. Standards, p. 259.

[3] See *Proceedings*, Am. Soc. Testing Mats., Vol 29, Part I, p. 880 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 834.

[4] 1927 Book of A.S.T.M. Standards, Part II, p. 796.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 875 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 829.

3. Thiefs. (a) General.—Thiefs shall be used for withdrawing samples of oil from drums, tank cars, or other containers *of 5-gal. capacity or larger* in which shipment is made. Glass or metal thiefs may be used.

Change Paragraph (*b*) to read as follows by the omission of the words in brackets:

(b) For Drums.—For sampling drums [or smaller containers] the thiefs shall be so designed that they will reach within approximately ⅛ in. (about 3 mm.) of the bottom and should have a capacity of approximately 1 pt. or 1 qt. (0.5 or 1 liter). [For sampling the smaller containers a proportionately smaller similar thief may be used.]

Reletter Paragraph (*c*) as Paragraph (*d*) and add the following as Paragraph (*c*):

(*c*) *For Cans.*—For sampling cans of 5-gal. capacity or larger a thief, similar to that used for sampling drums but of proportionately smaller dimensions, shall be used. Cans of less than 5-gal. capacity shall be taken as a whole (see Section 7 (*e*)).

Section 7 (*e*).—Change from the wording proposed in 1929: namely,

(*e*) Smaller containers, such as cans, shall be sampled with the drum thief or a proportionately smaller similar thief using a method similar in general to the one described for drums and barrels in Paragraph (*d*).

to read as follows:

(*e*) Smaller containers such as cans of 5-gal. capacity or larger shall be sampled with a thief, similar to the drum thief but of proportionately smaller dimensions, using a method similar in general to the one described for drums and barrels in Paragraph (*d*). To sample a shipment of cans of less capacity that 5-gal., one or more cans shall be selected at random from the shipment using the entire can (or cans) as the sample.

Tentative Methods of Testing Insulating Varnishes (*D 115 - 29 T*):[1]

Section 3. Viscosity Measurements.—For some little time it has been the practice of the Secretary of Committee D-9 to keep on file the description of the MacMichael Viscosimeter for distribution to those interested in the methods of determining viscosities of varnishes. It has been felt that it would be much more satisfactory if this description appeared with the methods. It is therefore recommended that the description of the method of calibrating the MacMichael Viscosimeter, which appears in Appendix I[2] to this report, be added as an appendix to the methods.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 728 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 554.

[2] This description has been incorporated in the Tentative Methods of Testing Insulating Varnishes, see p. 1179.—ED.

Sections 8 to 12. Dielectric Strength.—In last year's report mention was made that studies were under way to work out a suitable method for measuring the dielectric strength of insulating varnishes, particularly at elevated temperatures. The studies have been continued and a satisfactory method developed. It is therefore recommended that the method of testing insulating varnishes for dielectric strength and water absorption described in Sections 8 to 12, inclusive, be deleted and replaced by the procedure which appears in Appendix I.[1]

Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (D 149 – 27 T):[2]

Studies of the dielectric strength of laminated sheets by the step test method have shown that the values given for the initial voltage and the steps of increase of voltage are not adequate to take care of materials of high dielectric strength. It has been found that more satisfactory values can be applied to laminated sheets. It is therefore recommended that Section 19 of these methods be revised as follows:

Section 19.—Change from its present form: namely,

> 19. A voltage shall be applied which is equal to 40 per cent of the breakdown voltage obtained in the short-time test to the nearest 1000 volts (or 500 volts with low voltages). The voltage shall then be increased by 10 per cent of the initial value until failure occurs, the voltage being held at each step for one minute. When changing from one step to a higher step, the voltage shall be increased to the required value within 10 seconds.

to read as follows:

> 19. An initial voltage shall be applied equal to 40 per cent of the breakdown voltage in the short-time test, adjusted as shown in the following table. The voltage shall then be increased in increments as indicated in the table, up to failure, being held at each step for one minute. The change from each step to the next highest shall be made within 10 seconds.

BREAKDOWN KILOVOLTS BY SHORT-TIME METHOD	ADJUST 40 PER CENT OF BREAKDOWN VOLTAGE TO NEAREST	INCREMENT OF INCREASE
12.5 kv. or less	0.5 kv.	0.5 kv.
over 12.5 to 25 kv., inclusive	1.0 "	1.0 "
over 25 " 50 " "	2.5 "	2.5 "
over 50 " 100 " "	5.0 "	5.0 "
over 100 "	10.0 "	10.0 "

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[1] These new methods have been incorporated in the Tentative Methods of Testing Insulating Varnishes, see p. 1171.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 995 (1927); also 1929 Book of A.S.T.M. Tentative Standards, p. 577.

NOTE.—*Example:*

Breakdown voltage by short-time method = 41 kv.
40 per cent of breakdown voltage = 16.4 kv.
Initial voltage obtained by adjusting 40 per cent of breakdown voltage to nearest 2.5 kv = 17.5 kv.
Voltage will be increased in increments of 2.5 kv.
Therefore, second step = 20.0 kv., etc.

Tentative Methods of Testing Untreated Insulating Paper (D 202 - 29 T):[1]

Section 8.—At the present time this section requires the thickness to be determined by means of a spring-actuated, dial-type micrometer. It has been more or less the commercial practice to use the ordinary machinist's type of hand micrometer in making acceptance tests. In view of this fact the committee has been investigating the possibility of standardizing the use of the 1-in. machinist's type micrometer instead of the spring actuated dial type. It is, therefore, recommended that a note reading as follows be added to Section 8:

> NOTE.—Work is now under way in Committee D-9 toward standardizing the use of the 1-in. machinist's type micrometer.

Section 22.—At the present time, this section requires that ten bursts shall be made. Experience has shown that somewhat different results are obtained in this test for bursting strength, depending upon which side of the paper is uppermost. Consequently it seems very essential that bursting strength tests of paper be determined with first one and then the other side of the paper uppermost. It is, therefore, recommended that the first sentence of Section 22 be changed to read as follows by the addition of the italicized words:

> Ten bursts shall be made, *five with one side of the paper uppermost and five with the other side uppermost.*

It is also recommended that the procedure for the survey of conducting paths on paper appearing in the body of the methods be revised as follows:

Section 46.—Change this section from its present form to read as follows, by the omission of the two sentences in brackets:

> 46. The specimen shall be of relatively large area such as a pad of tape or a sheet from each sample of paper (see Section 2 (*a*)). [For sheet material such as press board either the entire sheet or a relatively large portion of a sheet shall be used. The specimen shall be representative of the shipment (see Section 2 (*a*)).]

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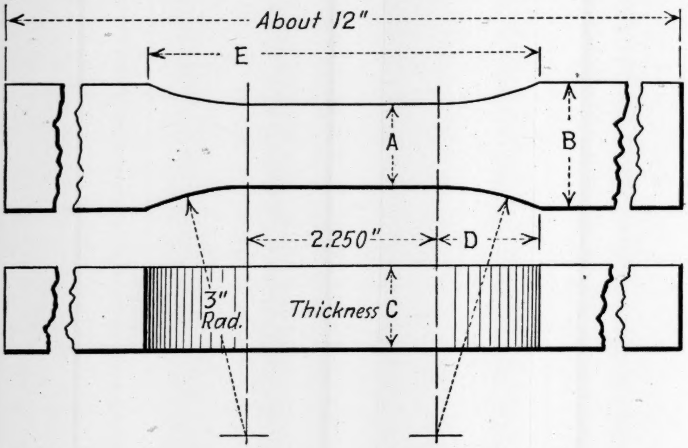
[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 758 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 602.

Section 47.—In the procedure for survey of conducting paths, Note 2 states that a description of the equipment and a procedure which has been found suitable for making this survey for conducting paths in different thicknesses of paper may be obtained upon application to the Secretary of Committee D-9. The demands for this information have been quite extensive and it has seemed that it would be advisable to include a description of the apparatus as a portion of the method. It is, therefore, recommended that the description of the equipment which has been found suitable for making the survey of conducting paths be included as an appendix to the Tentative Methods D 202 - 29 T. This description appears as Appendix II[1] to this report.



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in., D is 0.857", E is 3.964 in.
When C is $\frac{1}{8}$ in. or over, A is 1 in., B is $1\frac{1}{2}$ in., D is 1.199", E is 4.648 in.

FIG. 1.—Tension Test Specimen for Laminated Sheet Insulating Materials.

Section 48.—Omit this section which contains a reference to the Tentative Methods D 149 - 27 T.

Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229 - 28 T):[2]

Figure 1.—An error appears in the dimensions given for the tension test specimen for laminated sheet insulating materials, and in order that the specimen may be made properly, it is desirable that

correct dimensions be inserted. It is, therefore, recommended that Fig. 1 of these methods be replaced by the accompanying Fig. 1. The dimension 3.375 in. in the former Fig. 1 is to be changed to 3.964 in. for specimens less than $\frac{1}{8}$ in. in thickness and 4.648 in. for specimens $\frac{1}{8}$ in. in thickness or over. The dimension D, formerly 0.562 in., is to be changed to 0.857 in. for specimens less than $\frac{1}{8}$ in. in thickness and 1.199 in. for specimens $\frac{1}{8}$ in. in thickness or more.

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[1] This description has been incorporated in the Tentative Methods of Testing Untreated Insulating Papers, see p. 1212.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1013 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 617.

Flexural Strength.—In order to clarify the meaning of the term flexural strength, it is recommended that under the main heading "Flexural Strength" the following parenthetical phrase be added: "(Formerly Called Transverse Strength)."

Tests have been made which have shown that flexural strength can be determined on specimens having thicknesses of $\frac{1}{32}$ in. or over. Considerable data have been collected supporting this statement. It is therefore recommended that the statement under Flexural Strength be changed to read as follows, by the addition of the italicized figure and the omission of that in brackets:

> (A) For Materials [$\frac{1}{8}$] *$\frac{1}{32}$* in. Thick or Over

It is also recommended that the footnote to the above statement be changed to read as follows, by the addition of the italicized figure and the omission of that in brackets:

> Conventional flexure tests in a flatwise direction are not recommended for materials thinner than [$\frac{1}{8}$] *$\frac{1}{32}$* in. nor in the edgewise direction for materials thinner than $\frac{1}{4}$ in.

Section 11 (b).—For accurate results on materials thinner than $\frac{1}{8}$ in. special care is required in the arrangement of supports and in the measurement of the thickness of the specimen. In order to extend the test to thin materials it is found desirable to change Paragraph (*b*) from its present form: namely,

> (*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. The load shall be applied midway between the supports by a pressure piece, the bearing edge of which shall be rounded to a radius of $\frac{1}{8}$ in. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction.

to read as follows:

> (*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. for material $\frac{1}{8}$ in. or over in thickness, and to a radius of $\frac{1}{16}$ in. for thinner materials. For material thinner than $\frac{1}{8}$ in. both supports shall be provided with a pin or other stop to align one side of the specimen perpendicular to the line of contact with

the supports. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction, except that the minimum span shall be ½ in.

Section 18.—At the present time compressive strength tests cannot be made according to the accepted method for material less than 1 in. thick as it is impossible to get a 1-in. cube out of thinner materials. In order to extend the compression test to thinner materials a series of experiments have been made on piles of sheets 1 in. square and the results compared with those obtained for a solid 1-in. cube. The data showed definitely that results by the two methods corresponded very closely and each gave equally satisfactory results. It is therefore recommended that this section be changed from its present form: namely,

> 18. The test specimen shall be a 1-in cube. The faces shall be flat and perpendicular to the axes, being ground to this condition if necessary.

to read as follows:

> 18. (*a*) For sheets 1 in. in thickness or over, the test specimen shall be a 1-in. cube, the faces of which shall be flat and perpendicular to the axes, being ground to this condition if necessary.
>
> (*b*) For sheets less than 1 in. in thickness, the specimen shall consist of a pile of sheets 1 in. square with a minimum number of layers to produce a height of at least 1 in.

Section 19.—In order to clarify the method of procedure it is recommended that this section be changed from its present form: namely,

> 19. Three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.

to read as follows:

> 19. (*a*) For sheets 1 in. in thickness or over, three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.
>
> (*b*) For sheets less than 1 in. in thickness, three specimens shall be crushed in the condition in which they are received with the load applied flatwise of the sheet.

Tentative Methods of Testing Electrical Porcelain (D 116 – 29 T):[1]

In last year's report slight changes were made in the methods of testing electrical porcelain. During the past year nothing seems to have arisen in connection with these methods which would lead the committee to think that the methods are anything but entirely satisfactory. It is therefore recommended that these tentative methods be advanced as standard, without revision.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 738 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 564.

The following is the result of the letter ballot vote of the committee, which consists of 53 members, on the recommendations made in this report:

Items	Affirmative	Negative	Not Voting
I. PROPOSED NEW TENTATIVE STANDARD			
Proposed Tentative Method of Test for Comparing the Thermal Conductivities of Solid Electrical Insulating Materials	22	0	19
II. PROPOSED REVISIONS OF STANDARDS			
Standard Methods of Testing Molded Insulating Materials (D 48 - 29), immediate adoption	25	0	16
Standard Methods of Testing Electrical Insulating Oils (D 117 - 27)	27	1	13
III. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
Tentative Methods of Testing Insulating Varnishes (D 115 - 29 T)	23	0	17
Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (D 149 - 27 T)	26	0	15
Tentative Methods of Testing Untreated Insulating Paper (D 202 - 29 T)	27	0	14
Tentative Methods of Testing Laminated Sheet Insulating Materials (D 229 - 28 T)	22	0	18
IV. ADVANCEMENT OF TENTATIVE STANDARD TO STANDARD			
Tentative Methods of Testing Electrical Porcelain (D 116 - 29 T)	15	0	25

SUBCOMMITTEE ACTIVITIES

Subcommittee I on Insulating Varnishes (V. A. Ryan, chairman):

In addition to the work which Subcommittee I has done leading to the recommendations, mentioned earlier in the report, relative to the Tentative Methods of Testing Insulating Varnishes (D 115 - 29 T) with reference to the inclusion of a description of the MacMichael viscosimeter and the determination of the dielectric strength of insulating varnishes, the subcommittee has been carrying on work along other lines, which are mentioned in brief as follows:

1. *Acid and Alkali Proof Tests.*—Considerable work has been done in studying the measurement of acid and alkali proofness of varnish films. The most promising method at the present time seems to be one comprising the measurement of electrical conductivity of the film. This will be developed further during the coming year.

2. *Dielectric Strength.*—Having completed the work on dielectric strength tests at elevated temperatures and after water immersion, investigations are under way relative to the influence of time of baking or time of air drying on the ultimate dielectric strength. This, of course, will be pushed considerably during the coming year, and

in addition, an attempt will be made to study film hardness in conjunction with the drying.

3. *Hardness.*—Studies will be pushed rather rapidly in connection with the hardness of varnish films and the oil resistance through reduction of hardness by the new tester developed some time ago by the Westinghouse Electric and Manufacturing Co. It is hoped that this work may be sufficiently developed to lead to definite recommendations by the close of the year.

4. *Insulation Resistance.*—A new section of Subcommittee I has been formed to study the insulation resistance of varnish films under ordinary room conditions and at high humidities.

Subcommittee II on Molded Insulating Materials (A. M. Lynn, chairman):

As mentioned earlier in the report, this subcommittee is recommending the revision of the Standard Methods of Testing Molded Insulating Materials (D 48 - 29). Subcommittee II has been carrying on investigations with the idea of arriving at some definite conclusions in regard to methods of test along the following lines:

1. *Purchase Specifications.*—A study is being made of existing available methods of test for phenol resin molding compounds with a view to establishing standard purchase specifications covering this type of compound.

2. *Impact Fatigue.*—A program for the investigation of this characteristic of molded materials has been compiled and a testing machine is being constructed for the investigation of impact fatigue.

3. *Tolerances of Test Specimens.*—An investigation has been made on the effect of variations in dimensions of impact test specimens and the relationship of the impact strength to the factor "bd^2." This investigation has for its object the establishment of suitable tolerances for the standard impact specimens shown in the Tentative Methods of Testing Insulating Materials for Resistance to Impact (D 256 - 28 T).

4. *Type of Mold for Test Specimen.*—The advisability of definitely specifying the type of mold with which impact and flexure test specimens shall be molded is now under investigation.

5. *Future Activities.*—The principal activities of Subcommittee II for the coming year, in addition to the uncompleted work now under way, are as follows: The effect of moisture content on the strength of phenol plastic test specimens, and the development of methods of test for plasticity and rate of cure of phenol plastic molding compounds.

Subcommittee III on Sheet Insulation (Dean Harvey, chairman):

In addition to the recommendations mentioned earlier in the report relative to the revision of the Tentative Method of Testing Sheet and Tape Insulating Materials for Dielectric Strength (D 149 - 27 T), Methods of Testing Untreated Insulating Paper (D 202 - 29 T) and Methods of Testing Laminated Sheet Insulating Materials (D 229 - 28 T) which have resulted from work done by Subcommittee III, there have been several lines of new studies carried on during the year which are briefly noted as follows:

Section 1 on Insulating Paper.—An extensive investigation has been carried on with reference to the method of gaging paper for thickness. The section has been continuing the work mentioned in the report of 1929[1] in cooperation with the Technical Committee on Thickness Measurement appointed by Committee E-1 on Methods of Testing.

The question has been raised relative to determining the moisture content of the impregnated paper used for making joints in paper insulated cable. Investigations are being carried out in developing a method which will be sufficiently sensitive to measure the small amount of moisture present.

Work has also been done to develop material specifications for condenser tissue paper. A number of tests have been carried on for some time with a model of a new type of edge tearing tester. These have indicated the desirability of this type of test and a commercial type of machine is being developed.

For some time studies have been carried on with reference to methods of making folding endurance tests. It is hoped that a reliable test of this character may result.

Further studies are being carried on to determine acidity in insulating paper.

An automatic type of instrument for determining air resistance is also being studied.

Section 2 on Laminated Sheets.—Subcommittee III has been working in close cooperation with the recently organized Technical Committee of the Laminated Products Section of the National Electrical Manufacturers Association. By arrangement with the N.E.M.A., Subcommittee III is developing methods of test for laminated products and the technical commitee of the N.E.M.A. is using them in developing its standards for the various grades of material.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 452 (1929).

A considerable amount of work has been done in the development of a method of test for compressibility. The tests have been giving results showing the compressibility over a period of time. A momentary test is also under consideration using the Rockwell Hardness Tester.

Methods of making arc resistance tests on laminated products have been considered and it is hoped that a standard test method may be developed. The question of working up a test for insulation resistance for heavy laminated materials has been turned over to Subcommittee VIII.

A method for determining the dielectric strength of laminated sheets of high dielectric strength is being developed.

Section 3 on Deterioration of Sheet Insulating Materials.—Mr. A. C. Walker of the Bell Telephone Laboratories, Inc., has modified an experimental oven so that the temperature is very closely controlled throughout the oven and the air circulated by means of a fan. The first oven is now being manufactured and will soon be ready for test. Provision can also be made for humidity control in this oven.

Section 6 on Varnished Cloth and Varnished Cloth Tubing.–Methods of testing varnished tubing are being developed as a material specification. This section recommends that the following note be added as an editorial revision after Section 5 of the Tentative Methods of Testing Varnished Cloths and Varnished Cloth Tapes (D 295 - 29 T):[1]

NOTE.—Work is now under way in Committee D-9 toward standardizing the use of the 1-in. machinist's type micrometer.

The methods now require that the thickness be determined by means of a spring-actuated dial-type micrometer. It seems to be the commercial practice to use a machinist's type of hand micrometer in making acceptance tests. The subcommittee has been investigating the method of gaging paper by means of the machinist's hand micrometer and it seems that definite recommendations will soon be obtained. Meanwhile the committee reommends that the above note be added to Section 5 of the Tentative Methods.

Subcommittee IV on Liquid Insulation (E. A. Snyder, chairman):

As mentioned earlier in the report, this subcommittee is recommending a few minor changes in the tentative revision, proposed last year, in the sampling procedure of the Standard Methods of Testing

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[1] ***Proceedings***, Am. Soc. Testing Mats., Vol. 29, Part I, p. 786 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 643.

Electrical Insulating Oils (D 117 – 27). It is recommended that the new methods of sampling, as revised, be continued as tentative.

During the past year Subcommittee IV has been actively carrying on investigations relative to neutralization value, regular sludge tests, short-time sludge tests and moisture in oils, which are briefly commented on as follows:

Neutralization Value.—The subcommittee is actively engaged in the development of an electrometric titration method for determining the neutralization value of oils and the study of the relationship of such values to the resistivity value of the oil. During the year a proposed method was prepared and samples of oil have been distributed for test by various laboratories. In this investigation the section has had various types of methods under study. A differential method of titration using condensers and a ballistic galvanometer in order to eliminate the necessity of calculations and plotting of curves, shows some promise. A method developed by Mr. Harry Selz of the Carnegie Institute of Technology, using a silver - silver chloride electrode, is also under study. A method developed by F. M. Clarke of the Bell Telephone Laboratories, Inc., using radio amplifying tubes, also looks very promising. All of these various methods, in addition to the proposed method developed by the subcommittee, of course, are being further investigated and indications are that a tentative method will probably be developed and proposed during the coming year.

Sludge Tests.—Suitable methods for determining sludging characteristics of insulating oils continues to be the main subject of study by Subcommittee IV. During the year considerable time was spent on the development of sludge accumulation tests and sufficient evidence has been secured to indicate that such information, in addition to other sludge test data such as "life test," etc., is necessary in order to accurately predict the quality of an insulating oil.

A large amount of work has been done during the past 5 years in studying various types of sludge tests and attempting to develop a suitable standard method. In spite of the enormous amount of work, the subcommittee still feels that although the so-called "life test"[1] is the most promising of all tests so far investigated, there are, nevertheless, too great variations in test results taken on the same oil by different laboratories. Furthermore, it is felt that because of various criticisms of the test, it might be desirable to review the whole problem of oil oxidation, paying particular attention to some of the fundamentals of the problem. With this in mind, Subcommittee IV assigned to its various sections the following specific problems for study and report:

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[1] See *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 363 (1925).

1. Shall the oil receptacle be heated from the bottom rather than from the top as is done in the life test oven?
2. Shall the products of oil oxidation be returned to the oxidation chamber?
3. Is the oil depth to oil surface ratio of major importance?
4. Without the use of a catalyst is there a critical temperature for the oil sludging test?
5. How is the rate of sludge accumulation affected by the rate of air supply?
6. How does the presence of water or water vapor affect the sludge test run at 90° C.?
7. Are oils rated similarly with and without the presence of copper or copper oxide when tested at 90° C.?
8. Will sludge accumulation results by volume after centrifuging at high speeds (4000 to 4500 r.p.m.) give a correct estimate of the actual amount of sludge present?
9. What is the relation, if any, between sludge formation or accumulation and acid formation in the oxidized oil?

All of the above problems have been partially studied during the past year and will continue to be studied during the coming year.

While Subcommittee IV realizes the importance and desirability of having a suitable sludge test, it also wishes to call attention to the fact that the development of accelerated oxidation tests for complex and organic bodies, such as transformer oils, is an exceedingly difficult undertaking. During the year this matter was discussed with Hugh S. Taylor of Princeton University in his capacity as chairman of the American Petroleum Institute's Committee on Organic Reactions Related to Petroleum Products and he called attention to the large amount of work which had already been performed in their researches on accelerated oxidation tests of pure hydrocarbons. It is quite evident, from results of this work on the pure hydrocarbons, that Subcommittee IV cannot hope for great speed in the development of an oxidation test for complex hydrocarbons, such as insulating oils. The subcommittee proposes to continue its work during the coming year, but believes that up to the present time the best test for sludging properties of insulating oil is its behavior in the apparatus in which it is to be used.

Short-Time Sludge Tests.—The subcommittee is making some definite progress in the development of a short-time sludge test, which it should be pointed out, is intended for use merely in controlling the uniformity of shipments of one type of oil which has been approved as a satisfactory insulating medium for a definite purpose, and is not intended as an acceptance test of insulating oils prepared indiscriminately. The subcommittee hopes to have available by next year a tentative method of this character which will be of assistance along the more or less narrow lines as laid down above.

Moisture in Oils.—It was brought to the attention of the subcommittee during the year that because of the fact that metallic soaps often affect the dielectric strength of oils and that these are often carried in solution in moisture present in oils, there was some need for having a more accurate method for determining the amount of moisture in oils. A new section has been appointed in the subcommittee to study this problem and it hopes to be able to report some progress by next year.

Subcommittee V on Porcelain Insulation (L. E. Barringer, chairman):

As mentioned earlier in the report, this subcommittee is recommending that the Tentative Methods of Testing Electrical Porcelain (D 116 – 29 T) be advanced to standard without revision.

Subcommittee VII on Radio Frequency Tests (E. S. Lee, chairman):

Early in the year it was felt that the tests on radio frequency had proved themselves worthy of being advanced to standard. Recently a method of simplifying the circuit that is used in the Substitution Method of the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant at Frequencies of 100 to 1500 Kilocycles (D 150 – 27 T) has been suggested and work is now in progress in several laboratories to determine whether this simplified circuit will give reproducible results and as equally satisfactory results as the now existing measuring circuit. It was felt advisable not to advance the method to standard until after this information was available.

The industry has been circularized relative to an electric endurance test at high frequencies and it was found that there was practically no interest in such a test. Work on writing a method for this test has, therefore, been discontinued.

Measurements of power factor and dielectric constant at short wavelengths, such as from 15 to 30 meters, have not advanced to a place where standardization is practicable. The subcommittee is watching the progress of this work in the different laboratories where there is an interest in it.

Subcommittee VIII on Resistance and Power Factor Measurements (H. L. Curtis, chairman):

Subcommittee VIII has been carrying on an investigation relative to determining the resistivity of dielectrics and power factor of oils and solid materials at low frequencies.

Insulation Resistance.—The question of the resistivity of dielectrics has been given some attention. There seems to be a need of more definite specifications for measuring insulation resistance in connection with materials which absorb a large amount of moisture. This matter is under consideration and an effort will be made to so amend the present Tentative Methods of Test for Resistivity of Insulating Materials (D 257 - 29 T) to make it applicable to this class of materials.

Power Factor of Liquids.—The Section on Dielectric Constant and Power Factor of Liquid Dielectrics has distributed oil samples to several laboratories. These laboratories have measured the dielectric constant and power factor of the oil and the results have been tabulated. The results are so satisfactory that a start will be made immediately to prepare a method for measuring the power factor and dielectric constant of liquids.

Power Factor of Solids.—The Section on Power Factor and Dielectric Constant of Solids has distributed a set of samples to several laboratories and the results of measurements have been tabulated. There was greater variation in the results of the different laboratories than was expected. This was partly due to the fact that not all of the laboratories were equipped to measure the specimens that were submitted. Another more suitable set of samples has been prepared but the measurements upon them have not yet been completed.

At the Annual Meeting an election of officers was held for the ensuing term of two years. The committee unanimously elected H. L. Curtis, chairman; Dean Harvey, vice-chairman; and J. A. Scott, secretary.

This report has been submitted to letter ballot of the committee, which consists of 53 members; 44 returned their ballots, of whom 43 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

H. S. VASSAR,
Chairman.

T. S. TAYLOR,
Secretary.

EDITORIAL NOTE

The proposed Tentative Method of Test for Comparing the Thermal Conductivities of Solid Electrical Insulating Materials was accepted for publication as tentative and appears on page 1224.

The proposed revisions of the Standard Methods of Testing Molded Insulating Materials were approved at the annual meeting and subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930. The methods in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 980.

The proposed modifications of the revisions of the sampling procedure in the Standard Methods of Testing Electrical Insulating Oils published as tentative last year were accepted, the revisions as modified appearing on page 1280.

The proposed revisions of the Tentative Methods of Testing Insulating Varnishes; of Testing Sheet and Tape Insulating Materials for Dielectric Strength; of Testing Untreated Insulating Paper and of Testing Laminated Sheet Insulating Materials were accepted for publication as tentative. The methods as revised appear on pages 1169, 1188, 1197, and 1216.

The Tentative Methods of Testing Electrical Porcelain were approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 991.

REPORT OF COMMITTEE D-10

ON

SHIPPING CONTAINERS

Committee D-10 at this time wishes to report progress on the development and consideration of new standards for shipping containers.

During the past several years a large amount of work has been done by the U. S. Forest Products Laboratory and commercial organizations on the development of the fundamental principles of container design.

Many changes and improvements in handling and transportation conditions which affect container standards have also taken place. Members of the committee have worked closely with other organizations in developing and putting into practice specifications which follow the general plan of the specifications developed by Committee D-10.

Many of these specifications have considerable value in a limited field. Others like those recently prepared for the Federal Specifications Board are of a more general nature. The committee believes that the time is opportune for a general revision of the present A.S.T.M. tentative specifications for shipping containers and the preparation of new standards not only to deal with specifications for containers but also with the materials, nomenclature, and methods of tests. With these thoughts in mind, the subcommittees have been entirely reorganized. These subcommittees have been charged with the preparation of new standards, based on the existing A.S.T.M. specifications, the Federal specifications, and such other specifications as they may consider of value. The committee believes that the revised specifications should be of a very broad and basic nature, setting forth clearly the fundamental principles of container construction.

The committee accordingly recommends that the following tentative specifications under its jurisdiction, all of which have been tentative for three years or longer without revision, be continued as tentative:

Tentative Specifications for Wooden Boxes, Nailed and Lock-Corner Construction, for the Shipment of Canned Foods (D 44 – 20 T);

Tentative Specifications for Canned Foods Boxes, Wirebound Construction (D 45 – 17 T);

Tentative General Specifications for Wooden Boxes, Nailed and Lock-Corner Construction (D 68 – 22 T);

Tentative General Specifications for 4-One Boxes and Similar Type Boxes (D 118 – 21 T).

Much confusion has arisen from lack of standard definitions of terms. The subcommittees have all been directed to give particular attention to this matter. The committee has also directed its subcommittee to carefully consider specifications for materials which enter into various types of containers, methods of testing materials, and methods of testing the completed container.

Reports of progress that have been received from the subcommittee chairmen indicate that several new or revised specifications will be presented to the Society during the coming year.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 28 members; 24 returned their ballots, of whom 23 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

J. A. NEWLIN,
Chairman.

C. A. PLASKETT,
Secretary.

REPORT OF COMMITTEE D-11
ON
RUBBER PRODUCTS

Committee D-11 on Rubber Products held one meeting during the year in addition to the annual meeting. This was at Detroit, Mich., on March 19, 1930, during the Spring Group Committee Meeting.

The committee recommends at this time that the eight standards and six tentative standards dealing with rubber products be continued in the present status. It has no new tentative standards to recommend at present, though work is in progress in the subcommittees as noted below which will lead to extensive revisions in at least three of the present tentative standards and to one new tentative standard.

The committee further recommends that the Standard Specifications for Rubber Matting for Use Around Electrical Apparatus or Circuits Not Exceeding 3000 Volts to Ground (D 178 – 24) and Standard Specifications for Friction Tape for General Use for Electrical Purposes (D 69 – 28) be submitted to the American Standards Association for approval as American Tentative Standard under the Proprietary Standards Method of A. S. A. Procedure. Both of these specifications are in wide use and have become generally accepted as satisfactory.

The Tentative Specifications for Steam Hose (D 54 – 24 T) have stood for more than 3 years without any action. As reported last year, these specifications are to be revised to conform with revisions in the specifications of the American Railway Association. For the present, the committee is not ready to recommend action. A tentative revision of the Standard Specifications for Rubber Pump Valves (D 151 – 23) has also stood for more than three years. The committee has given this standard some consideration but there seems to be some differences of opinion as yet and the committee does not wish to recommend action until agreement can be reached. The specifications for pump valves have secured only limited use.

There have been numerous changes in personnel during the year. On March 7, the chairman, Mr. L. C. Conradi, found it necessary to resign from that office and from membership on the committee because of change in employment and cessation of direct interest in rubber products. The committee wishes to record its appreciation of the service rendered to it by Mr. Conradi during his term of office and membership. Mr. D. F. Clash, Assistant Vice-President, The Whitehead Brothers Rubber Co., Mr. W. H. Bassett, Jr., Technical Superintendent and Metallurgist, The Anaconda Wire and Cable Co., and Mr. E. L. Lasier, Laboratory Manager, United States Testing Co., Inc., were elected to membership on the committee. Mr. C. R. Mummery, The Hoover Co., replaced Mr. H. M. Teague. Mr. Gordon Thompson, Electrical Testing Laboratories, replaced Mr. F. M. Farmer. The committee records with sorrow its loss in the death of Mr. W. S. Clark of the General Electric Co. Mr. C. H. Zieme was appointed chairman of Subcommittee II on Belting, replacing Mr. E. H. Grafton, resigned. Mr. A. W. Carpenter was appointed chairman of Subcommittee X on Standard Procedure for Testing Rubber Products, replacing Mr. W. A. Gibbons, resigned. Mr. F. D. Abbott was appointed chairman of Subcommittee XVII on Rubber Products for Absorbing Vibration, replacing Mr. L. C. Conradi, resigned.

ACTIVITIES OF SUBCOMMITTEES

Advisory Subcommittee.—The Advisory Subcommittee held a meeting in New York on November 13, 1929, at which time it was decided to again omit the usual fall meeting of the committee because the work had not progressed sufficiently since the annual meeting to require an additional one at this time. The subcommittee gave consideration to the advisability of strengthening the program for the annual meeting in June in so far as rubber products are concerned and it was decided to sponsor a Symposium on Rubber Belting. To this end, three papers dealing with rubber belting have been secured[1] and an additional paper dealing with flexing tests as applied to the pneumatic tire carcass will be presented.[2]

Subcommittee I on Mechanical Rubber Hose (H. E. Morse, chairman).—The program on investigation and standardization of test methods for steam hose has not yet been developed to the point where the subcommittee is ready to report.

Subcommittee II on Belting (C. H. Zieme, chairman).—A new specification covering methods of test and classification of rubber belting for power transmission has been prepared by this subcommittee and is under consideration at present. The subcommittee is not yet ready to make definite recommendations but it is expected that this work will lead to a new tentative standard on power transmission belting.

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[1] C. W. Staacke, "Stretch in Rubber Transmission Belting;" E. G. Kimmich, "Service Tests on Rubber Belting;" J. E. Skane, "Performance Characteristics of a 4-in. 4-ply Rubber Transmission Belt, Branded Condor", see *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, pp. 944, 957, 928 (1930).

[2] H. A. Depew and H. C. Jones, "Laboratory Flexing as an Aid in Investigating the Pneumatic Tire Carcass," see *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 965 (1930).

Subcommittee IV on Protection of Persons from Electric Shock (H. S. Vassar, chairman).—As reported last year, the subcommittee was requested by the National Electric Light Association to prepare a specification for gloves for electrical workers on apparatus or circuits not exceeding 8000 volts to ground and work to this end was authorized. As this work proceeded, it developed that electricians' gloves consisting of rubber or rubber parts deteriorated with great rapidity when used on high voltages owing to the effects of corona discharge and the production of ozone. The subcommittee has, therefore, reported that it does not consider feasible the preparation of specifications for gloves for use at voltages higher than 3000 volts to ground until a rubber compound or some other suitable glove material has been developed that is more resistant to attack by ozone. The subcommittee is cooperating with glove manufacturers and with the National Electric Light Association in the securing of comprehensive data covering the field performance of electrical gloves. It is hoped through these studies to improve the product from the standpoint of durability and to incorporate the practical results of these developments in the glove specifications.

Subcommittee V on Insulated Wire and Cable (C. B. Martin, chairman).—The work of this subcommittee has progressed with considerable activity during the year. The subcommittee decided not to recommend advancement to standard at this time of the tentative specification under its jurisdiction. The subcommittee also decided that the advance of the art requires the preparation of a specification for a 30 per cent rubber compound so modified as to permit the use of organic accelerators and anti-oxidants. It was suggested that such a specification be prepared independent of the Tentative Specifications for Insulated Wire and Cable; 30-per-cent Hevea Rubber (D 27-28 T) and a proposed specification was submitted by the chairman to be used as a basis for discussion. The subcommittee decided to revise the present specification and to include both the oxygen bomb and the Geer life tests. The Section on Performance Specifications submitted a tentative specification which is being given detailed consideration. Due to the resignation of Mr. Honan, it has been necessary to reorganize this section under the chairmanship of Mr. R. A. Schatzel. This section is working on modifications of the present tentative specifications to permit the use of accelerators and anti-oxidants and on the revision of the Performance Specifications with the idea of incorporating these in a single standard.

Subcommittee X on Physical Testing (A. W. Carpenter, chairman). —This subcommittee is engaged in the revision of the Standard Methods of Testing Rubber Products (D 15 – 24) to bring this standard into conformity with the "Standard Outline of Laboratory Procedure," recommended by the Physical Testing Committee of the Rubber Division, American Chemical Society. The standard outline seems to be especially suited to the requirements of rubber chemists and research workers but it is not entirely suitable in its present form for use by the consumers of rubber products. It is intended in this revision to give consideration so far as possible to inclusion of such special tests of performance and properties as have been developed through the work of other subcommittees of Committee D-11.

Subcommittee XI on Chemical Analysis (S. Collier, chairman).—Subcommittee XI has been instructed to proceed with the revision of the Tentative Methods of Chemical Analysis of Rubber Products (D 297 – 29 T) in so far as they are affected by the presence of anti-oxidants and organic accelerators. The subcommittee is engaged in accumulating the necessary data but is not ready to make definite recommendations at this time.

Subcommittee XIV on Abrasion Tests (H. A. Depew, chairman).—This subcommittee is engaged in studying known tests of cutting and tearing. It has developed that considerable information is known about such tests in individual laboratories which has not been published. The subcommittee, therefore, proposes to secure as much information as possible regarding these various methods and will endeavor to arrange a symposium of papers on this subject at a subsequent meeting.

Subcommittee XV on Life Tests for Rubber Products (Stanley Krall, chairman).—This subcommittee is continuing the accumulation of data in the series of aging tests previously reported. It is to be understood that correlation of accelerated tests with natural life necessarily requires considerable time and will spread over several years before final report can be rendered.

Subcommittee XVI on Flexing Tests for Rubber Products (W. L. Sturtevant, chairman).—The subcommittee is presenting a brief report covering the investigation program which has been carried out on the Scott flexing machine. Details of parts of this work have been previously reported.[1] The subcommittee has obtained a vast amount of data and concludes that the machine is of value in research work but that it is not at the present time possible to secure sufficiently precise results to warrant its use in purchase specifications by purchasers of rubber products such as transmission belting and tires.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 470 (1926).

Subcommittee XVII on Rubber Products for Absorbing Vibration (F. D. Abbott, chairman).—The Section on Hardness Testing is engaged in a revision of the Tentative Method of Test for Hardness of Soft Rubber (in Slab Form)(D 314 – 29 T) but is not yet ready to submit recommendations. The revisions will be largely of an editorial nature and will not affect the fundamentals of the testing devices or methods. The section is also considering modification of the method to adapt it for use with soft rubbers beyond the range of the present standard. The Section on Compression or Flow Testing has accumulated considerable data on present tests which show wide variations, even when the tests were supposedly made to conform to what was considered a reasonably rigid specification. It is very clear that this section has a real problem in developing a standard test covering a phase of specification testing which is of great importance in the automotive field. The section is not yet ready to make definite recommendations. The subcommittee has been requested by several members in the automobile industry to devote some attention to an elasticity test.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 61 members; 28 members returned their ballots, of whom 25 have voted affirmatively and none negatively.

Respectfully submitted on the behalf of the committee,

W. B. WIEGAND,
Chairman.

A. W. CARPENTER,
Secretary.

REPORT OF COMMITTEE D-13
ON
TEXTILE MATERIALS

Committee D-13 on Textile Materials held two meetings during the past year, one in Providence, R. I., on October 17 and 18, 1929, and one in Charlotte, N. C., on March 13 and 14, 1930. A third meeting will be held in conjunction with the annual meeting of the Society in June. There was a registration of 71 members and guests at the October meeting, and 114 at the March meeting. This bespeaks a growing interest in the work of the committee. It is particularly gratifying to note the fine attendance at the southern meeting. A number of interesting papers were presented at the meetings.

The present membership of the committee consists of 153 members, of whom 59 are classed as producers, 46 as consumers, and 48 as general interests.

RECOMMENDATIONS AFFECTING STANDARDS AND TENTATIVE STANDARDS

The recommendations of the committee affecting standards and tentative standards under its jurisdiction are summarized below together with the analysis of the letter ballot on each item. Comments, where necessary, are made under Subcommittee Activities.

I. *Proposed Revisions of Existing Standards.*—The committee recommends that the revisions in the following standards, which are given in full in the Appendix to this report, be submitted to letter ballot of the Society. These revisions are divided into two groups:

Group A.—Revisions in the following standards, recommended for publication as tentative for one year before referring them to letter ballot of the Society for adoption as standard (items Nos. 1 and 2 of the Appendix):

Standard General Methods of Testing Woven Textile Fabrics (D 39 – 27);[1]

Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 29).[2]

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 900.

[2] 1929 Supplement to Book of A.S.T.M. Standards, p. 162.

Group B.—Revision in the following standards which the committee recommends be referred to letter ballot of the Society immediately by the required nine-tenths vote of the annual meeting for adoption as standard (items Nos. 3 and 4, Appendix):

Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (D 122 – 27);[1]

Standard Specifications for Tolerances and Test Methods for Cord Tire Fabrics (D 179 – 27).[2]

II. *Proposed Revisions of Tentative Standards.*—The committee recommends the revisions in the following tentative specifications, which are given in full in the Appendix (items Nos. 5 and 6), be approved and that the specifications as thus revised be continued as tentative for another year:

Tentative Specifications for Chafer Tire Fabrics (D 316 – 29 T);[3]

Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 – 29 T).[4]

III. *Advancement of Tentative Standards to Standard.*—The committee recommends that the definitions of the terms Loop-Knot, Gage and Regain which have been tentative since 1928 as a part of the Tentative Definitions of Terms Relating to Textile Materials (D 123 – 28 T)[5] be revised as indicated in the Appendix (item No. 7) and referred to letter ballot of the Society for adoption as standard to be incorporated in the Standard Definitions of Terms Relating to Textile Materials (D 123 – 27). The definitions as revised are in accordance with the recommendations of Committee E-8 on Nomenclature and Definitions.

IV. *Withdrawal of Tentative Standard.*—The committee recommends the withdrawal of Tentative Methods of Testing Cotton Fibers (D 152 – 22 T).[6] This action is deemed advisable because the committee feels that the methods suggested are not accurate and dependable and it would be better to wait until some of the research work now under way indicates methods more accurate and more dependable.

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 884.

[2] *Ibid.*, p. 888.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 825 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 739.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 827 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 747.

[5] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1105 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 770.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part I, p. 973 (1922); also 1929 Book of A.S.T.M. Tentative Standards, p. 741.

V. *Tentative Standards Continued as Tentative.*—The committee recommends that the following tentative standards be continued as tentative for another year without revision:

- Tentative Specifications for Tolerances and Test Methods for Knit Goods (D 231 – 28 T);
- Tentative Specifications for Tolerances and Test Methods for Rayon (D 258 – 27 T);
- Tentative Specifications and Tests for Cuban (Jute) Raw Sugar Bags (D 275 – 27 T);
- Tentative Specifications for Asbestos Tape for Electrical Purposes (D 315 – 29 T);
- Tentative Methods of Testing Grease Wool and Allied Fibers for Scoured Content (D 232 – 25 T).

The above recommendations have been submitted to letter ballot of the committee, the results of which are set forth in the following table:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISIONS OF STANDARDS			
1. Standard Methods of Testing Woven Textile Fabrics (D 39 – 27)	33	1	9
2. Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 29)	30	1	12
3. Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (D 122 – 27), immediate adoption	25	0	18
4. Standard Specifications for Tolerances and Test Methods for Cord Tire Fabrics (D 179 – 27), immediate adoption	22	0	21
II. PROPOSED REVISIONS OF TENTATIVE STANDARDS			
5. Tentative Specifications for Chafer Tire Fabrics (D 316 – 29 T)	27	1	33
6. Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 – 29 T)	24	0	19
III. ADVANCEMENT OF TENTATIVE STANDARDS TO STANDARD			
7. Tentative Definitions of Terms Relating to Textile Materials (D 123 – 28 T)	28	0	15
IV. WITHDRAWAL OF TENTATIVE STANDARDS			
8. Tentative Methods for Testing Cotton Fibers (D 152 – 22 T)	28	0	15

SUBCOMMITTEE ACTIVITIES

Subcommittee A-1 on Cotton (K. B. Cook, chairman):

Section I on Cotton (H. W. Barre, chairman).—This section has been conducting important research work on the factors influencing the strength and length of cotton fibers. Its work has led to the recommendation that the present Tentative Methods of Testing Cotton Fibers (D 152 – 22 T) be withdrawn for the reasons stated above. Work in progress should lead to more acceptable methods.

Section II on Cotton Yarns and Threads (R. H. Adams, chairman).—This section is considering certain recommendations affecting test methods.

Section III on Light and Medium Cotton Woven Fabrics (R. T. Fisher, chairman).—This section is recommending the revision of the Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 29) by the addition of the test procedure for tear resistance (item No. 1, Appendix) and recommends that the added method be issued as a tentative revision for a year. This section is ready to prepare specifications for specific materials for which there is a demand.

Section IV on Tire Fabrics (B. H. Foster, chairman).—This section has been active in revising the specifications under its jurisdiction. The revisions are given in detail under items Nos. 4, 5, and 6 in the Appendix to this report. As revised they represent the latest test methods as devised by a special committee of consumers and manufacturers and which have been in satisfactory use for approximately a year. For this reason the recommendation is made that they be adopted immediately. The immediate adoption of items Nos. 4 and 5 will require the nine-tenths vote at the annual meeting which is accordingly being requested.

The section is also recommending revision of the tensile strength requirements of certain constructions in the Tentative Specifications for Chafer Tire Fabrics (D 316 – 29 T).

Specifications for breaker fabrics, enamelling ducks, and napped sheetings will be developed in the near future.

Section V on Hose, Belt and Numbered Duck (B. L. Whittier, chairman).—This section is studying the use of a new type of jaw for testing heavy fabrics. It is also considering the advisability of drawing up specific specifications for fabrics within its scope.

Section VI on Narrow Fabrics (J. B. Sidebotham, chairman).—This section has outlined specifications for 0.007 in. thick electrical cotton tape. Tape conforming to these specifications is being given a thorough trial.

Subcommittee A-2 on Rayon (A. M. Tenney, chairman):

Section I on Rayon (A. M. Tenney, chairman).—This section is very actively engaged in a study of revisions necessary in the Tentative Specifications for Tolerances and Test Methods for Rayon (D 258 – 27 T). It is carrying on cooperative work with the Bureau International pour la Standardisation des Fibres Artificielles, Basle, Switzerland, for the purpose of harmonizing in so far as possible the two sets of test methods. For this reason it recommended that the specifications be continued as tentative for another year.

Section II on Rayon Fabrics (M. D. C. Crawford, chairman).—This section has been recently organized and has not had an opportunity to start work. It is planning to hold a special meeting to outline problems for study.

Subcommittee A-5 on Jute, Ramie and Linen (A. E. Davieau, chairman):

Section I on Sugar Bags (A. E. Davieau, chairman).—During the past three years members of this section have been endeavoring, without success, to have the Tentative Specifications and Tests for Cuban (Jute) Raw Sugar Bags (D 275 - 27 T) recognized by the Indian Jute Mills Association of Calcutta. Other agencies are at work and it is hoped that recognition will be granted or desirable changes made evident. In view of the above the recommendation is made that the specifications be continued as tentative for another year.

Subcommittee B-1 on Methods and Machines (W. D. Appel, chairman):

Section I on Methods (W. D. Appel, chairman).—This section has been given jurisdiction over the Tentative Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 - 27 T) and is recommending a revision of the method of analysis of cotton and wool mixtures (item No. 7, Appendix), the specifications so amended to remain tentative for another year.

It is also recommending a method for measuring tear resistance (item No. 1, Appendix) as a tentative revision of the Standard General Methods of Testing Woven Textile Fabrics (D 39 - 27).

This section is cooperating with the Subcommittee on Rayon in revising the methods for identification of the various types of rayon; studying methods of measuring thickness; and test methods for yarns and cords.

Section II on Machines (H. J. Ball, chairman).—This section is considering a revision of the Standard Specifications for Textile Testing Machines (D 76 - 27), involving the use of pins on the jaws of tension testing machines to bring the jaws into alignment at the time of inserting the test piece. A comprehensive study of the important subject of abrasion is being made.

Section III on Humidity (G. B. Haven, chairman).—This section has been studying the matter of moisture regain in various types of materials, for example, fabrics, yarns, bale cotton, wool and rayon, in cooperation with the subcommittees having jurisdiction over these materials. It is also studying methods of measuring relative humidity and the effect of moisture on the elongation of tire cord.

In view of the work in progress on regain in wool it is recommended that the Tentative Methods of Testing Grease Wool and Allied Fibers for Scoured Content (D 232 - 25 T) be continued as tentative for another year.

At the request of Committee E-10 on Standards that every standing committee have an Editorial Committee to review all specifications and methods of test before they are submitted to the Society for adoption, Mr. W. E. Emley of the U. S. Bureau of Standards has been appointed to act in this capacity.

The following officers were elected for the two-year period from June, 1930, to June, 1932:

Chairman, Herbert J. Ball;
First Vice-Chairman, Kenneth B. Cook;
Second Vice-Chairman, Robert H. Adams, and
Secretary, William H. Whitcomb.

This report has been submitted to letter ballot of the committee, which consists of 153 members; 57 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

W. H. WHITCOMB,
Chairman.

J. E. SKANE,
Secretary.

EDITORIAL NOTE

The proposed revisions of the Standard General Methods of Testing Woven Textile Fabrics and of the Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics were accepted for publication as tentative and appear on pages 1280 and 1279, respectively.

The proposed immediate revision of the Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics and for Tolerances and Test Methods for Cord Tire Fabrics was approved at the annual meeting by a unanimous vote and subsequently adopted by letter ballot of the Society on September 2, 1930. The standard specifications in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part II, pages 1081 and 1085, respectively.

The proposed revisions of the Tentative Specifications for Chafer Tire Fabrics and of the Methods for Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods were approved. The tentative specifications and methods in their revised form appear on pages 1229 and 1231.

The definitions of the terms loop knot, regain (moisture regain) and gage as revised, appearing in the Tentative Definitions of Terms Relating to Textile Materials, were approved at the annual meeting and were subsequently adopted as standard by letter ballot vote of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Part II, page 1107.

The withdrawal of the Tentative Methods of Testing Cotton Fibers was approved.

APPENDIX

PROPOSED REVISIONS IN STANDARDS AND TENTATIVE STANDARDS FOR TEXTILE MATERIALS

In this appendix are given the proposed revisions of standards and tentative standards referred to in the body of this report and for ease of reference are numbered from 1 to 7, inclusive. Reference is also given to the publications in which each standard appears in its present form.

I. Proposed Revisions of Standards

No. 1. *Standard Methods of Testing Woven Textile Fabrics (D 39 – 27)*:[1]

New Section.—Add the following new test procedure as Section 14 under Test Methods:

(*H*) Tear Resistance

14. (*a*) *Preferred Method.*—A specimen 3 in. in width and 8 in. in length shall be selected for test. A longitudinal cut 3 in. in length shall be made in the center of the specimen. One of the tongues thus formed shall be placed in the upper jaw of a tensile strength testing machine, preferably with automatic recording device, and the other in the lower jaw. The machine shall then be started and the specimen torn, the speed of the pulling jaw being 12 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been started shall be considered to be the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

(*b*) *Alternate Method.*—A specimen 3 in. in width and 6 in. in length shall be selected for test. An isosceles trapezoid having an altitude of 3 in. and with bases 1 in. and 4 in. in length, respectively, shall then be marked on the specimen with the aid of a template. A cut $\frac{1}{4}$ to $\frac{3}{8}$ in. in length shall then be made in the center of the 1-in. length and perpendicular to it. The specimen shall then be clamped in the jaws of the tensile strength testing machine along the non-parallel sides of the trapezoid. The initial distance between the jaws shall be 1 in., and the width of the jaws shall be 3 in. or more. One edge of the specimen shall thus be held taut while the other edge lies in folds. The machine shall then be started and the sample torn, the speed of the pulling jaw being 3 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been started shall be considered as the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

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[1] **1927 Book of A.S.T.M. Standards, Part II, p. 900.**

No. 2. *Standard Specifications for Tolerances and Test Methods for Certain Light and Medium Cotton Fabrics (D 274 – 29)*:[1]

New Section.—Ass as a new Section 8 the tear resistance test procedure described above under item No 1

No. 3. *Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (D 122 – 27)*:[2]

Section 3.—Change from its present form: namely,

3. The weight per square yard of the roll or piece determined by test shall not be more than:

(*a*) Two and one-half per cent over or under the specified weight per square yard for fabrics over 11 oz. per sq. yd. in weight.

(*b*) Three per cent over or under the specified weight per square yard for fabrics 11 oz. per sq. yd. or lighter.

to read as follows:

3. (*a*) The weight per square yard of an individual roll or piece determined by test shall not be more than 2.5 per cent over or under the specified weight per square yard for fabrics over 11 oz. per sq. yd. in weight and not more than 3 per cent over or under the specified weight per square yard for fabrics 11 oz. per sq. yd. or lighter.

(*b*) The average weight per square yard of a shipment of 10 or more rolls or pieces as determined by test shall not be more than 1.5 per cent over or under the specified weight per square yard for fabrics over 11 oz. per sq. yd, and not more than 2 per cent over or under the specified weight per square yard for fabrics 11 oz. per sq. yd. or lighter.

A shipment of less than 10 rolls shall be considered as individual rolls.

New Section.—Insert in the body of the specifications as a new Section 10 the present reference to Methods D 39, now appearing as a footnote, renumbering the subsequent sections accordingly.

Section 14.—In the second paragraph, change the next to the last sentence to read as follows, by the addition of the italicized figure and the omission of the figure in brackets:

The speed of the pulling jaw shall be [20] *12* in. per minute.

Add a new third paragraph under this section to read as follows:

Tensile strength shall be determined either in dry condition or standard condition as defined in Sections 2 and 3 of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39) of the American Society for Testing Materials, by either the strip or grab test as specified in Section 12 of the Standard Methods D 39, as may be required in purchase or fabric specifications.

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[1] 1929 Supplement to Book of A.S.T.M. Standards, p. 162.

[2] 1927 Book of A.S.T.M. Standards, Part II, p. 884.

No. 4. *Standard Specifications for Tolerances and Test Methods for Cord Tire Fabrics (D 179 – 27)*:[1]

The revisions proposed in these specifications include a change in the title, the addition of a new paragraph to Section 3 covering a tolerance on the average weight of shipments of 10 or more rolls or pieces, and a complete revision of the methods of testing. These specifications in their revised form are appended hereto.[2]

No. 5.—*Tentative Specifications for Chafer Tire Fabrics (D 316 – 29 T)*:[3]

Table I.—Change the tensile strength requirements given in Table I for the constructions indicated to read as follows by the addition of the italicized figures and the omission of those in brackets:

			8-oz. Fabric 14/2 ply Construction	9-oz. Fabric 10/2 ply Construction	12-oz. Fabric 12/4 ply Construction
Tensile Strength, lb.	Grab Test, Conditioned	Warp	[105] *100*	[120] *115*	[155] *145*
		Filling	[115] *110*	[130] *125*	[165] *155*
	Grab Test, Bone Dry..	Warp	[75] *70*	[80] *75*	[105] *100*
		Filling	[80] *75*	[90] *85*	[115] *110*

No. 6.—*Tentative Method of Identification of Textile Fibers and Their Quantitative Determination in Mixed Goods (D 276 – 29 T)*:[4]

Under "Quantitative Separations of Samples Containing Two or More Kinds of Fibers" omit the procedures for "Cotton and Wool Mixtures" replacing Method A for wool content over 15 to 20 per cent, and Method B for wool content under 15 to 20 per cent with the following test procedure:

> Remove the sizing and finishing materials by extracting in ether, boiling in distilled water for 10 minutes, treating in a hot (90 to 95° C.) solution of sodium carbonate (0.5-per-cent) for 30 minutes, rinsing in distilled water, immersing in a hot (85 to 90° C.) solution of HCl (0.5-per-cent) for 30 minutes, rinsing in distilled water, neutralizing in a solution of sodium carbonate (1-per-cent) at room temperature, rinsing thoroughly in distilled water and drying. All weighing shall be made after the specimen has been conditioned at 65 per cent relative humidity, and 70° F. Weighings shall be made to the nearest milligram or equivalent accuracy. Gently boil the specimen in at least 100 times its weight of a solution of potassium hydroxide (5-per-cent) for 10 to 15 minutes. Rinse in hot distilled water, then in a solution of acetic acid (5-per-cent) and again

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[1] 1927 Book of A.S.T.M. Standards, Part II, p. 888.

[2] The revised specifications were adopted and appear in the 1930 Book of A.S.T.M. Standards, Part II, p. 1085.—Ed.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 825 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 739.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 827 (1929); also 1929 Book of A.S.T.M. Tentative Standards, p. 747.

in distilled water. Filter, then dry in air and condition the specimen. The percentage of cotton present shall be calculated from the following formulas:

$$\text{Weight of cotton} = \frac{\text{Weight of residue}}{97} \times 100$$

$$\text{Percentage of cotton} = \frac{\text{Weight of cotton}}{\text{Original weight of specimen}} \times 100$$

No. 7.—*Tentative Definitions of Terms Relating to Textile Materials (D 123 - 28 T)*:[1]

Loop Knot.—Change to read as follows, by the addition of the italicized words and the omission of those in brackets:

> *Loop Knot.*—Snarl or curl produced by a [weft] *filling* yarn [receding] *coiling* upon itself.

Regain (*Moisture Regain*).—Change from its present form: namely,

> *Regain* (*Moisture Regain*).—The percentage of moisture present in a textile material calculated on its absolute dry weight.

to read as follows:

> *Regain* (*Moisture Regain*).—In the case of textiles the moisture present expressed as a percentage of the dry weight of the material, as determined by definite prescribed methods.

Gage.—Change from its present form: namely,

> *Gage.*—In the case of knit goods, the closeness of the wales, that is, the longitudinal row of loops per inch, a measure of the fineness of the fabric. It is expressed by the number of needles in 1½ in.

to read as follows:

> *Gage.*—In the case of knit goods, a measure of the fineness of the fabric as determined by the closeness of the wales, that is, the longitudinal row of loops.
>
> NOTE.—It is expressed by the number of wales or needles in 1½ in.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1105 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 770.

REPORT OF COMMITTEE D-14
ON
SCREEN WIRE CLOTH.

Committee D-14 held one meeting during the past year, that being in connection with the annual meeting of the Society in Atlantic City.

The exposure tests on non-ferrous screen-wire cloth undertaken by the committee have been in position over 4 years and failures have now been reported. Coincidental with the exposure tests there has also been obtained analyses of the atmospheres for SO_2 content. The chairman of Subcommittee IV on Testing of Wire Screen Cloth, Mr. G. Willard Quick, has prepared a paper giving the results of the exposure tests to date as well as of the variation in atmospheric SO_2 content at the various stations. This paper is submitted as an Appendix to this report.

The activities of the committee are largely confined to carrying out the exposure tests and reports on the status of these tests will be submitted at such times as additional data of interest are available.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 15 members; 14 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

R. W. Woodward,
Chairman.

W. H. Bassett,
Secretary.

APPENDIX

ATMOSPHERIC EXPOSURE AND LABORATORY TESTS ON NON-FERROUS SCREEN WIRE CLOTH[1]

By G. Willard Quick[2]

Introduction

The 1925 report of Committee D-14[3] described the material selected, and composition, the types of frames used and the locations selected for exposure tests of non-ferrous screen wire cloth. Photographs of the specimens mounted at Pittsburgh, Pa., Portsmouth, Va., Panama Canal, Canal Zone, and at the U. S. Bureau of Standards were published in the 1926 report.[4] At the time this latter report was written, no reports of the condition of the materials at any of the stations other than the U. S. Bureau of Standards had been received. In the appendix to the report results as expressed by loss in weight of some laboratory tests made on the seven materials, including salt-spray tests, dipping tests in dilute acid, and sodium-chloride solutions, were given. The tensile strength of the material also was given.

Supplementary Tests

Since the 1926 report[4] was made several supplementary tests have been in progress; namely, tensile evaluation of salt-spray deterioration; the effect of atmospheric-corrosion on the tensile strength at the Bureau of Standards; and the determination of the sulfur-dioxide content of the air at the test locations.

Tensile Evaluation of Salt Spray Tests.—Tensile evaluations of the effect of corrosion in the salt spray were determined by placing eleven-strand reduced-section tension test specimens edgewise in a glass rack which in turn rested in a hard-rubber tray. Ten or twelve specimens taken longitudinally and a like number taken transversely from the screen cloth, were exposed simultaneously. Specimens in duplicate were tested in tension at intervals during the period. The tensile strength of the specimens as determined at the time of removal was plotted against the time of exposure. The method of tension testing is described in the 1926 report.[4] The results of these tests are shown in Fig. 1.

Tensile Evaluation of Additional Specimens Exposed at the Bureau of Standards.—In addition to the regular series of specimens exposed in the three types of frames, other pieces of each material were exposed at the Bureau one year later for periodic tensile evaluation of the effects of exposure. It was the intention to clip tension test specimens, both longitudinally and transversely, from these materials quarterly. The effect on the tensile strength after 3 months was so slight that the intervals have been gradually increased to about yearly tests. Fig. 2 show the effect of exposure on the strength of eleven-strand reduced-section specimens. The results of the tests are given in two parts to avoid too much overlapping of the curves. The loss of strength was only slight in the exposure of about $3\frac{1}{2}$ years. Some of the materials unexpectedly showed an apparent increase in strength during the early months of exposure.

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[1] Published with the approval of the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Associate Metallurgist, U. S. Bureau of Standards, Washington, D. C.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 384 (1925).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 487 (1926).

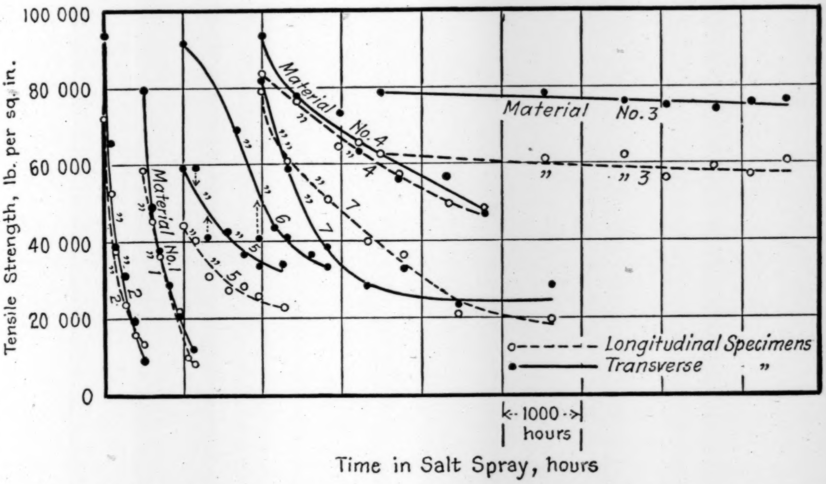

FIG. 1.—Effect of Salt Spray on the Tensile Strength of Seven Screen Materials. All except material No. 6 were tested both longitudinally and transversely.

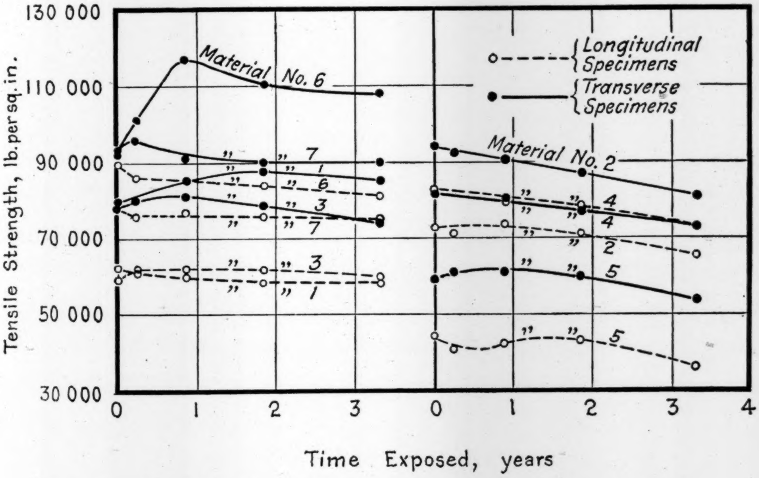

FIG. 2.—Variations in Tensile Strength During Exposure of the Materials at the Bureau of Standards.

There is enough material being exposed to carry on these tests at the present rate, for perhaps ten or more years, so that it seems that the results to be obtained give promise of being of considerable value.

Atmospheric Sulfur at Exposure Stations.—Mr. Robert J. McKay, Superintendent of Technical Service, The International Nickel Co., expressed the opinion that the value of data from the exposure tests on screens would be much greater if interpreted in the light of the weather and of the sulfur content of the atmosphere. The International Nickel Co. offered to furnish the necessary equipment for making sulfur dioxide determinations which was said to be very simple to operate, and not to require the services of a skilled chemist for accurate results.[1] Each determination can be made in approximately three minutes, which includes taking the sample, titration and recording of results. The analytical results are expressed as parts per million (by volume) of SO_2 The method will determine H_2S as well as SO_2 if both are present. Ordinarily the H_2S content of the atmosphere is so low as to be safely neglected as has been done in the present report.

TABLE I.—RESULTS FROM WASHINGTON WEATHER BUREAU STATION.

Month	Number of Observations	Sulfur Dioxide Content, parts per million			Month	Number of Observations	Sulfur Dioxide Content, parts per million		
		Maximum	Minimum	Average			Maximum	Minimum	Average
November, 1927	14	0.45	0	0.16	May, 1928	26	0.35	0	0.08
December, 1927	25	1.10	0	0.21	June, 1928	25	0.25	0	0.07
January, 1928	25	0.65	0	0.16	July, 1928	21	1.20	0	0.11
February, 1928	25	1.20	0	0.27	August, 1928	27	0.45	0	0.11
March, 1928	27	1.30	0	0.23	September, 1928	19	0.90	0	0.22
April, 1928	25	0.45	0	0.09	October, 1928	27	1.75	0	0.53

After considerable correspondence, arrangements were made to have sulfur dioxide determinations made frequently at (1) the Weather Bureau Station, American University, Washington, D. C., (2) the U. S. Bureau of Mines Station, Pittsburgh, Pa., (3) the Panama Canal, and (4) the Norfolk Navy Yard, Portsmouth, Va.

The reports from the Washington Weather Bureau Station covered almost daily observations over a period of 2 years and included data on the dust particles per cubic foot, the relative humidity, pressure, the clouds, wind velocity and direction, visibility and sulfur dioxide content in parts per million.

The Pittsburgh Station of the Bureau of Mines made almost daily tests for sulfur dioxide, in the atmosphere at Pittsburgh from August 11, 1927, to August 11, 1928.

The Norfolk Navy Yard at Portsmouth, Va., made tests over a period of 11 months from November, 1926, to September, 1927, inclusive, and gave the weather conditions, wind direction and velocity, wet and dry bulb temperatures, and sulfur dioxide content in parts per million. The observations were not as numerous as those of the Weather Bureau, and covered only five or six months.

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[1] The Selby Smelter Commission method in a somewhat modified form is described by R. J. McKay, and D. E. Ackerman, "Determination of Sulfur Dioxide in Small Amounts in the Atmosphere." *Industrial and Engineering Chemistry*, Vol. 20. pp. 538-543 (1928).

The Panama Canal made determinations of the sulfur dioxide content during May, June, July, August, September and October, 1927, and in May, June, July, August and September, 1928, and also gave data on the weather, temperature, relative humidity, wind direction and velocity.

The following summary is given of the results as to sulfur dioxide determinations at the four locations of test:

I. *Washington, D. C.:* The results from the Washington Weather Bureau Station are shown in Table I.

II. *Pittsburgh, Pa.:*

The results of the tests for sulfur dioxide at the Pittsburgh Experiment Station, U. S. Bureau of Mines were reported as their "Report of Investigation 3005." Since the report is not long it follows verbatim:

SULFUR DIOXIDE IN THE AIR IN THE PITTSBURGH EXPERIMENT STATION OF THE U. S. BUREAU OF MINES[1]

BY E. G. MEITER[2] AND C. E. TRAUBERT[3]

The daily sulfur dioxide content of the air at the Pittsburgh Experiment Station of the U. S. Bureau of Mines was determined by the bureau at the request of Committee D-14 on Screen Wire Cloth of the American Society for Testing Materials. The purpose of the investigation was to obtain data for use in interpreting screen-corrosion tests, which were conducted simultaneously and jointly by the committee[4] and the Bureau of Mines.

Plan of Investigation.—The plan of this investigation was to make a single daily determination, except on Sundays and holidays, of the SO_2 content of the atmosphere at the exposed test screens, for a period of 1 year. No attempt was made to determine the variation during the day, except on the morning of October 15, 1927, when the atmosphere was unusually foggy and smoky. Several successive determinations were made on that date to ascertain changes in the SO_2 as the morning haze disappeared. The SO_2 determinations were begun on August 11, 1927, and continued until August 11, 1928.

Sampling Station.—The Pittsburgh Experiment Station of the Bureau of Mines is in a residential section about 3 miles east of the central or main business district of Pittsburgh. The air samples were taken on the roof above the auditorium, or the center rear of the building. This was also the place where the pieces of screen were placed for corrosion tests. The height was about 40 ft. above ground level. Several sources of considerable smoke and SO_2 are in the immediate vicinity. On the west side of the building is a double-track railroad. At this point the line runs through a cut below the level of the building. The horizontal distance between the air-sampling position and the railroad tracks is about 400 ft., and the vertical distance about 70 ft. The power plant for the Bureau of Mines building is about 250 ft. south of the sampling position. About 1000 ft. farther to the south are the engineering building and power plant of Carnegie Institute of Technology, and one-quarter mile to the southwest is the power and heating plant for the Carnegie Library and Museum. About 1 to 2 miles farther south and also southwest are large steel mills and other industries. To the west and north are apartment houses and residences, and almost wholly residences for 2 or 3 miles east. Numerous freight and passenger trains pass this point, and as there is a considerable grade much smoke is often emitted. Smoke and gases from the industrial and residential districts thus come to the sampling position from almost any direction and regardless of the wind conditions more or less smoke is nearly always present. Bituminous and semi-bituminous coal is mainly used in this section for domestic and industrial fuel. This is supplemented by anthracite and oil with a considerable amount of natural gas for private homes.

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[1] Reprinted from the U. S. Bureau of Mines, "Report of Investigation 3005."

[2] Associate Chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

[3] Junior Advanced Inorganic Chemist, Pittsburgh Experiment Station, U. S. Bureau of Mines.

[4] Report of Committee D-14 on Screen Wire Cloth, *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 562 (1927).

Method of Analysis.—The general analytical procedure used in this investigation for determining the SO_2 content of Pittsburgh air was that developed by the Selby Smelter Commission.[1, 2]

TABLE II.—SUMMARY OF SO_2 DETERMINATIONS FOR THE PERIOD AUGUST 11, 1927, TO AUGUST 11, 1928

Month	Number of Determinations	Concentration of SO_2, parts per million by volume												Average SO_2, parts per million	Average Wind Velocity, miles per hour
		0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1		
		Number of Days													
August	18	8	3	5	2	..	..	..	..	..	..	..	..	0.11	6
September	25	5	..	4	4	3	3	2	3	1	..	..	..	0.35	7
October	26	2	1	..	1	2	..	5	2	4	6	1	2	0.67	7
November	23	13	2	4	2	2	..	..	..	..	..	..	..	0.10	13
December	25	14	3	6	1	1	..	..	..	..	..	..	..	0.09	14
January	25	13	5	4	2	1	..	..	..	..	..	..	..	0.09	13
February	24	4	8	9	1	2	..	..	..	..	..	..	..	0.15	11
March	27	3	9	12	3	..	..	..	..	..	..	..	..	0.16	11
April	25	18	4	2	1	..	..	..	..	..	..	..	..	0.04	13
May	26	12	6	5	3	..	..	..	..	..	..	..	..	0.10	7
June	26	20	4	2	..	..	..	..	..	..	..	..	..	0.03	10
July	25	22	2	..	1	..	..	..	..	..	..	..	..	0.02	6
August	9	7	..	1	1	..	..	..	..	..	..	..	..	0.06	6
Total days for year	304	141	47	54	22	11	3	7	5	5	6	1	2	....	..
Percentage of total days	...	46.38	15.46	17.76	7.24	3.62	0.99	2.30	1.64	1.64	1.97	0.33	0.66	....	..

Briefly, the method consists of drawing sample by the vacuum method into a bottle containing iodine-starch solution, which oxidizes the sulfur dioxide. The oxidizing solution is then withdrawn and brought to the same intensity of blue as a blank by the addition of standard iodine solution. It is possible to detect 0.1 part per million of SO_2 by this method. Samples that produce no preceptible color change are considered as zero concentration.

Results of Tests.—A total of 309 determinations was made during the period mentioned; with the apparatus described, of these 304 were single daily determinations. The remaining (5) were made at half-hour intervals on the morning of October 15, 1927, when the atmosphere was unusually foggy and smoky, and it was desired to ascertain changes in SO_2 as the morning fog disappeared. Nearly all determinations were made between 8 and 10 a.m. eastern standard time.

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[1] J. A. Holmes, E. C. Franklin, and R. A. Gould, Report of the Selby Smelter Commission, *Bulletin No. 98*, U. S. Bureau of Mines, pp. 200-204 (1915).

[2] The Selby Smelter Commission method in a somewhat modified form is described by R. J. McKay and D. E. Ackerman, "Determination of Sulfur Dioxide in Small Amounts in the Atmosphere." *Industrial and Engineering Chemistry*, Vol. 20, pp. 538-542 (1928).

The detailed test data included concentrations of SO_2 in the air, wind direction, wind velocity and observations relating to smoke, fog and clouds. These data were taken from the viewpoint of possible correlation with variations in SO_2 content of the air, but as no significant correlations were found, they are omitted from this report. Brief reference is given later, however, to certain indicated trends. Table II is a summary of the results.

Discussion of Results.—Table II shows that the concentration of SO_2 varied from 0.0 to 1.1 parts per million of air. On 141 days of the 304 days, or 46.38 per cent of the time, no SO_2 could be detected by the method of analysis employed (minimum detectable 0.1 parts per million). The maximum found was 1.1 parts per million and occurred on 2 days. On 134 days, or 44.08 per cent of the time, the concentration varied between 0.1 and 0.4 parts per million inclusive. On 29 days or 9.54 per cent of the time the concentration was 0.5 parts per million or above. The daily average for the year was 0.16 parts per million.

Table II also shows that the concentration of SO_2 was highest during October, with an average of 0.67 parts per million and a maximum of 1.1, the highest found in the year. The latter was found on 2 days of the month and at times when an unusually dense fog and smoke prevailed. On 20 days, or a total of 26 samples taken in October, the concentration of SO_2 was above 0.5 parts per million; many of these days were also unusually foggy and smoky.

TABLE III.—TESTS MADE ON OCTOBER 15 TO SHOW CHANGE IN CONCENTRATION OF SO_2 WITH DISAPPEARANCE OF FOG.

Time of day, A.M.	Parts of SO_2 per million part of air	Wind		Weather Conditions
		Intensity	Direction	
9:00	1.1	Light	Northeast	Dense fog and smoke
9:30	0.7	Light	Northeast	Fog somewhat lighter than at 9:00 A.M.
10:00	0.9	Light	North	Fog more dense than at 9:30 A.M.
10:30	0.8	Light	North	Conditions about same as at 10:00 A.M.
11:00	0.9	Light	North	Fog raised but still hazy
12:00	0.2	Light	Southeast	Sun now bright and sky clear

Table III gives the results of a series of tests made on the morning of October 15, 1927, when an unusually heavy fog and smoke prevailed. The tests continued over the period of disappearance of the condition.

Table III shows that the concentration of SO_2 decreased with the disappearance of fog from a maximum of 1.1 parts per million at 9:00 A.M. to 0.2 parts per million at noon. The wind velocity was light and remained the same during the test period. A change in wind direction occurred but is not thought to be important because of the prevailing low velocity and also because direction of wind was in general found to be an unimportant factor in the variation of the sulfur dioxide concentrations. The only major variable was the change in fogginess.

The lowest concentrations of SO_2 were found during the months of June and July, with an average of 0.03 and 0.02 parts per million, respectively. In June, 20 samples of a total of 26 showed zero concentration and during July none could be detected on 22 of a total of 25 days.

Although no direct relationship can be established between the variations of SO_2 content and weather conditions certain trends were observed. Of the various items making up the weather, the wind velocity was perhaps the greatest factor influencing the concentration of SO_2 in the air. There was roughly an inverse relation between wind velocity and concentration of SO_2 and a direct relation between fog and smoke and the concentration of SO_2. As a rule, the determinations reported in this paper were made in the morning, when smoke and fog conditions were generally denser than later in the day, consequently the results may be higher than the average for the day. The direction of the wind seems to have no definite effect. Determinations made during a rain or following a rain usually showed zero concentration.

III. *Panama Canal, C. Z.:*

Date	Number of Tests Made	SO_2 Content, parts per million			Date	Number of Tests Made	SO_2 Content, parts per million		
		Maximum Variation		Average			Maximum Variation		Average
		Plus	Minus				Plus	Minus	
May 23, 1927	6	0.37	0.22	0.74	July 9, 1928	7	0.04	0.07	0.13
May 25, 1927	6	0.28	0.27	0.55	July 13, 1928	10	0.17	0.05	0.11
June 3, 1927	8	1.20	0.72	1.00	July 16, 1928	10	0.15	0.13	0.24
June 7, 1927	6	0.42	0.42	0.70	July 18, 1928	8	0.21	0.13	0.24
June 9, 1927	7	0.52	0.32	0.60	July 19, 1928	5	0.11	0.11	0.28
June 21, 1927	7	0.08	0.20	0.36	July 20, 1928	5	0.09	0.13	0.19
June 24, 1927	6	0.31	0.25	0.53	July 24, 1928	8	0.11	0.11	0.17
June 25, 1927	6	0.42	0.14	0.42	July 25, 1928	7	0.10	0.06	0.12
July 7, 1927	7	0.22	0.23	0.34	July 26, 1928	8	0.11	0.11	0.17
July 11, 1927	6	0.20	0.8	0.36	July 27, 1928	4	0.04	0.07	0.24
August 16, 1927	6	0.22	0.23	0.34	July 30, 1928	7	0.19	0.09	0.15
August 17, 1927	6	0.38	0.35	0.46	August 3, 1928	7	0.10	0.06	0.12
September 15, 1927	7	0.14	0.8	0.14	August 6, 1928	7	0.12	0.10	0.16
September 23, 1927	8	0.30	0.21	0.26	August 7, 1928	5	0.07	0.04	0.10
October 6, 1927	8	0.29	0.21	0.27	August 8, 1928	5	0.19	0.16	0.20
May 31, 1928	6	0.13	0.06	0.15	August 9, 1928	6	0.12	0.04	0.10
June 6, 1928	7	0.14	0.08	0.14	August 14, 1928	6	0.02	0.03	0.09
June 8, 1928	6	0.27	0.12	0.29	August 15, 1928	6	0.14	0.14	0.25
June 12, 1928	8	0.17	0.05	0.11	August 16, 1928	5	0.09	0.02	0.13
June 14, 1928	8	0.14	0.14	0.20	August 21, 1928	6	0.16	0.12	0.23
June 16, 1928	5	0.08	0.03	0.09	August 23, 1928	5	0.06	0.05	0.11
June 18, 1928	6	0.05	0.06	0.06	August 29, 1928	8	0.17	0.28	0.39
June 21, 1928	7	0.22	0.17	0.23	September 6, 1928	7	0.12	0.10	0.16
June 28, 1928	7	0.40	0.14	0.20	September 7, 1928	6	0.13	0.09	0.15
June 29, 1928	7	0.10	0.12	0.18	September 11, 1928	8	0.21	0.07	0.18

Summary.—1. A total of 304 determinations of the SO_2 content of air at the Pittsburgh Experiment Station of the Bureau of Mines was made on 304 days during the period August 11, 1927, to August 11, 1928. The average amount found was 0.16 parts per million. The maximum, 1.1 parts per million was found on 2 days and less than the minimum detectable (less than 0.1 parts per million) on 141 days. On 134 days the concentration was between 0.1 and 0.4 parts per million inclusive and on 29 days the concentration was 0.5 to 1.1 parts per million.

A general observation was made that the concentration tended to be higher on foggy or smoky days. Also the concentration decreased with increase in wind velocity. The direction of the wind was not found to be a significant factor in changing the concentration.

IV. *Portsmouth, Va.:*

Month	Number of Observations	SO_2 Content, parts per million			Month	Number of Observations	SO_2 Content, parts per million		
		Maximum	Minimum	Average			Maximum	Minimum	Average
November, 1926	12	1.0	0.2	0.48	May, 1927	2	1.2	0.9	1.05
January, 1927	7	1.2	0.8	0.99	June, 1927	6	1.1	0.7	0.88
February, 1927	4	1.1	0.9	1.00	July, 1927	4	1.3	1.0	1.17
March, 1927	6	1.2	0.6	1.00	August, 1927	4	1.2	0.9	1.05
April, 1927	4	1.0	0.8	0.95	September, 1927	4	1.3	1.0	1.15

STATUS OF ATMOSPHERE EXPOSURE TESTS

The 1926 report of Committee D-14[1] gives the details regarding the exposure conditions at the four locations. The status of the tests up to the present time is as follows:

I. *Washington, D. C.:*

The specimens were exposed on the roof of the Far West Building, Bureau of Standards, on May 28, 1925 and have been up since, except for about five months during April 1 to August 1928 when they were stored during the repair of the roof and the installation of new supports.

Inspections were made from time to time as follows:

May 28, 1925.—Exposed.

May 29, 1925.—Few drops of rain that fell during the night spattered stains on screen Nos. 1 and 2 and 11 and 12 which were the copper-zinc alloys of 10 and 20 per cent zinc, respectively.

Other inspections during the month showed a tendency for all seven materials gradually to assume the same appearance.

July 3, 1925.—On this date one was unable to distinguish any difference between the materials. There was no patina or highly colored products on any of the screens but rather a dirty brownish rusty coating which did not appear very thick on any of the specimens.

December 19, 1925.—No marked change from previous inspection. In both of the sets of wood frames colorations were noted on the white paint below the cloth. Monel screens showed the least coating. Aluminum bronze slightly more and the other five materials had still more stain on their frames, with no observable difference among them. There was no deterioration or evidence of greater corrosion at the intersection of the wires than elsewhere; neither was there any evidence of any electrolytic action between the cloth and the copper frames.

The screens were inspected several times a year since January 1, 1926, and in each case the findings were the same: (1) nothing to distinguish one specimen from the other, (2) relatively thin coating on all of the specimens, (3) no failures of any kind. On three of these inspections the author was accompanied by members of Committee D-14, Messrs. Bassett, Woodward and Beers. These men agreed as to the results and all predicted that the materials would last a long time at the Bureau.

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[1] *Loc. cit.*

II. *Pittsburgh, Pa.:*

The sets of specimens were exposed on the roof of the Auditorium of the Bureau of Mines, on October 29, 1925. A photograph of the racks in position was published in the 1926 report of Committee D-14.[1] Reports of inspections received from time to time are given below. The final report listed shows a failure in screen No. 24, which is Monel metal, in the 12 by 12-in. wooden frame. Figure 3 is a photograph of this specimen. This is the only failure reported thus far in Pittsburgh, but it is observed that the corrosion was much more severe than for the specimens in Washington.

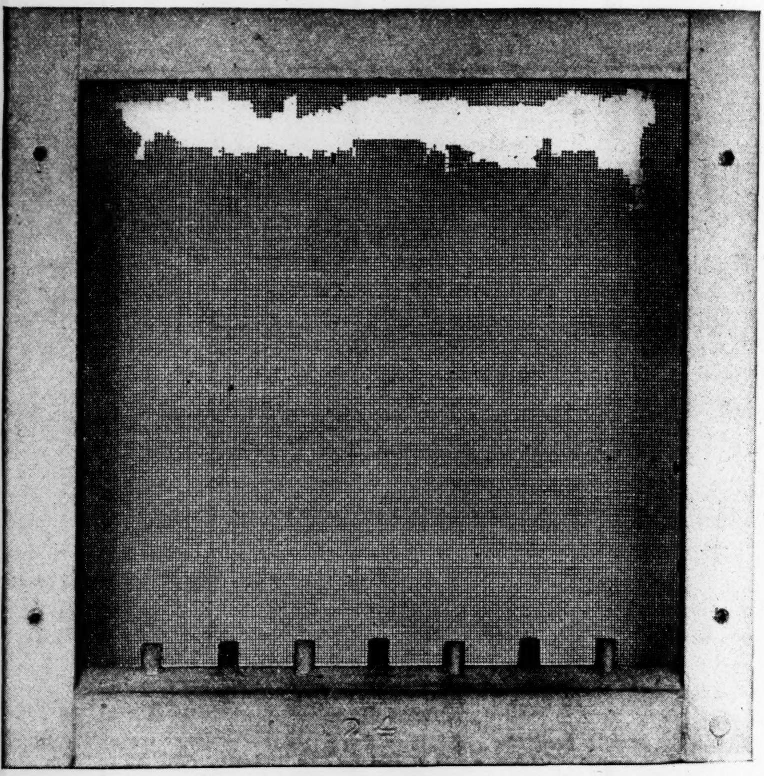

FIG. 3.—Photograph of 12 by 12-in. Specimen (70-per-cent Nickel, 30-per-cent Copper Alloy) in Frame No. 24 Removed at Pittsburgh After 4 Years' Exposure.

October 30, 1925.—After 24 hours' exposure the screens showed no perceptible discoloration. A wet snow fell during the night of October 29 and during the day of October 30.

November 3, 1925.—Screens have all discolored, that is have darkened uniformly. No rain or snow has fallen except that mentioned under inspection of October 30.

November 6, 1925.—All of the screens besides being darkened in appearance show a slight spotty discoloration, except screens Nos. 14, 4, and 24 which have no spotty discoloration but are uniformly darkened. A rain fell on November 5.

November 10, 1925.—No noticeable change since inspection of November 6, except that screens Nos. 13, 3, and 23 have developed a spotty discoloration more pronounced than before. A heavy rain fell on November 7.

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[1] ***Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 487 (1926).**

November 14, 1925.—Screens Nos. 13, 3, and 23 still show spotty discoloration. The other screens are all uniform in appearance being uniformly darkened. Rain fell during November 12 and 13.

December 3, 1925.—Screens Nos. 13, 3 and 23 do not show the pronounced spotty discoloration referred to under inspections of November 10 and 14. All of the screens are about the same color being darkened uniformly. Rather peculiar condition exists on screens Nos. 14, 4 and 24. Screens Nos. 14 and 4, on the lower half of the screens, have considerable white, transparent substance which is apparently a corrosion product. This material completely fills some of the mesh openings and about half fills some of the mesh openings. Screen No. 24 has only a little of this material in the meshes, in one of the lower corners of the screen.

December 4, 1925.—The corrosion product referred to, under inspection of December 3, on screens Nos. 14, 4, and 24 is practically all gone. A rain fell in the night of December 3 which apparently washed away most of this corrosion product.

December 10, 1925.—Screens all practically the same in appearance, being uniformly darkened. The corrosion product referred to, under inspections of December 3 and 4, on screens Nos. 14, 4, and 24 is entirely gone.

NOTE.—No records of rain or snow were recorded after November 14, 1925.

January 4, 1926.—It had rained previous to the inspection and the screens were slightly wet. Screens Nos. 14, 4, and 24 showed corrosion products in a number of the meshes. This corrosion product was scattered generally over the screens and not confined to any particular area. In some cases the mesh openings were completely filled, in other instances the corrosion product filled only a part of the mesh opening. The other screens had no unusual appearance but were discolored quite uniformly.

January 5, 1926.—Screens Nos. 11, 12, 13, 15, 16, 17, 1, 2, 3, 5, 6, 7, 21, 22, 23, 25, 26, and 27 showed the usual uniform dark discoloration. Screens Nos. 14, and 4 had considerable corrosion products in the meshes; screen No. 24 had a little of this corrosion product in the meshes.

February 1, 1926.—All the screens were darkened uniformly. Screens Nos. 14, 4, and 24 did not have any of the corrosion products observed in the previous two inspections. Apparently this product is soluble in water and comes and goes according to the weather conditions prevailing.

February 23, 1926.—Nothing unusual observed except in case of screens Nos. 14 and 4 which had considerable yellowish corrosion products on the wires; screen No. 24 had only a little of this corrosion product.

March 1926.—No inspection made during March; however, inspection on April 7, 1926 showed no unusual phenomena, all the screens being uniformly darkened.

May 11, 1926.—Nothing unusual observed, all the screens were uniformly darkened and practically of the same appearance.

June 2, 1926.—Same appearance as reported under inspection of May 11.

June 28, 1926.—Apparently no change in appearance of the screens; same as given under inspection of May 11.

General Remarks.—While the screens have much the same appearance, being uniformly darkened in appearance, it is possible that there may be considerable difference in the relative amount of corrosion of the wire in the different types of screens. By this is meant that the dark corrosion product covering the wires may be of different depth for the different types of wire. This corrosion product covers the underlying uncorroded wire so it is not possible by visual inspection to determine the depth and extent of the corrosion. It is possible that only a very thin layer of corrosion products exists in some types of wire and that a thicker layer exists in other types.

July, 1926.—No inspection made during month of July.

August 2, 1926.—No apparent change in appearance of screens except in case of Nos. 14, 4, and 24 some of the corrosion products have come off at some places exposing the underlying metal.

September 10, 1926.—Same appearance as for the August 2, inspection.

September 29, 1926.—Same appearance as for August 2, except that considerably more of the corrosion products have come off the wire of screens Nos. 14, 4, and 24.

November 1, 1926.—All screens of practically the same appearance, being covered with usual dark-colored corrosion products.

December 23, 1926.—All screens were covered with the usual dark-colored corrosion products. Screens Nos. 4, 24, and 14 had some light-colored corrosion products on the wires. Screens Nos. 5, 15, 25, 6, 16 and 26 had considerable of the dark-colored corrosion product removed, exposing the underlying metal of the wires.

February 17, 1927.—All screens were about the same in appearance, being uniformly discolored by corrosion products. Some of the corrosion products were removed from the wires of screens Nos. 2, 4, 12, and 14 exposing more or less of the underlying metal.

April 20, 1927.—Same appearance as of February 17 inspection, except that screens Nos. 14, 4, and 24 were the only ones that had corrosion products removed from the wires.

June 13, 1927.—Screens practically the same appearance; the wire cloth being darkened by corrosion products. No failures.

August 9, 1927.—Same as of June 13, except that screens Nos. 14, 4, and 24 had some of the corrosion products removed from the wire in different places.

October 1, 1927.—Screens practically the same appearance; the wire cloth being covered with dark corrosion products.

December 1, 1927.—Screens uniform in appearance except that screens Nos. 14 and 4 showed some light colored corrosion products in the wire at places.

January 26, 1928.—Screens all practically the same in appearance. Wires covered with dark corrosion products.

March 21, 1928.—Same as of January 26, 1928.

May 24, 1928.—Same as of January 26, 1928.

August 9, 1928.—Same as of January 26, 1928.

December 3, 1928.—Same as of January 26, 1928.

March 18, 1929.—Same as of January 26, 1928.

December 10, 1929.—Screen No. 24 had failed so was removed and photographed. A considerable area of wire cloth was completely gone.

Screen No. 11 showed a spotty appearance due to the fact that the corrosion products had been washed off of the screen cloth in certain areas, whereas, in other areas these corrosion products adhered to the wires.

Screen No. 12 had a spotty appearance but not so pronounced as screen No. 11.

Screen No. 13 showed a spotty appearance about to the same extent as No. 11.

Screen No. 14 was of a fairly uniform appearance in that the wires were quite thick with corrosion products. In some places the wires, however, appears thin due to the corrosion products being washed away.

Screen No. 15 was very uniform in appearance. The wires were not heavily coated with corrosion products.

Screen No. 16 was uniform in appearance. A few of the vertical wires were heavily coated with corrosion products.

Screen No. 17 wires were uniformly and heavily coated with corrosion products.

The above screens are the copper frame screens. The corresponding screens in the wood frames and the small 12 by 12-in. wood-frame screens presented in general the same appearance as described above.

III. *Panama Canal, C. Z.:*

The three sets of screens in the 30 by 36-in. wooden frames, the 30 by 36-in. copper frames and the 12 by 12-in. wooden frames were carefully inspected for colorations, splices, etc. and shipped to Panama on August 4, 1925, and later word was received that the frames were exposed November 16, 1925. A photograph received at that time was published in the 1926 committee report.[1] The following reports regarding the condition of the specimens at Panama are incorporated here for record and ease of access:

November 16, 1925.—Exposed.

April 1, 1926.—Aside from change in color there is no apparent defection of any kind.

Rain fall was as follows:

January	0.70 in.
February	1.78 in.
March	0.43 in.
Total	2.91 in.

October, 1926.—No change since last report. Rain fall was as follows:

April	0.34 in.
May	13.73 in.
June	31.23 in.
July	16.15 in.
August	20.84 in.
September	10.45 in.

January 1, 1927.—No further change since last report. Rain fall was as follows:

October	15.31 in.
November	29.39 in.
December	7.60 in.

July 1, 1927.—No further change since last report. Rain fall was as follows:

January	4.60 in.
February	3.21 in.
March	1.27 in.
April	6.93 in.
May	14.11 in.
June	13.74 in.

October 1, 1927.—No change in appearance in any of the frames since last report. Rain fall was as follows:

July	18.64 in.
August	26.63 in.
September	17.32 in.

October 1, 1928.—None of the frames showed appreciable change since last report, except the following:

Frame No. 2, heavy corrosion with some flaking off of corroded metal.
Frame No. 3, same as No. 2.
Frame No. 6, some corrosion, no flaking.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 487 (1926).

Frame No. 12, light corrosion, no flaking.
Frame No. 13, heavy corrosion with rough appearance.
Frame No. 23, heavy corrosion, flaking and peeling—same appearance as rust flaking from steel.

April 1, 1929.—No change except as follows:
Frame No. 3, shows corrosion and flaking.
Frame No. 14, shows corrosion and flaking.
Frame No. 24, shows corrosion and flaking.

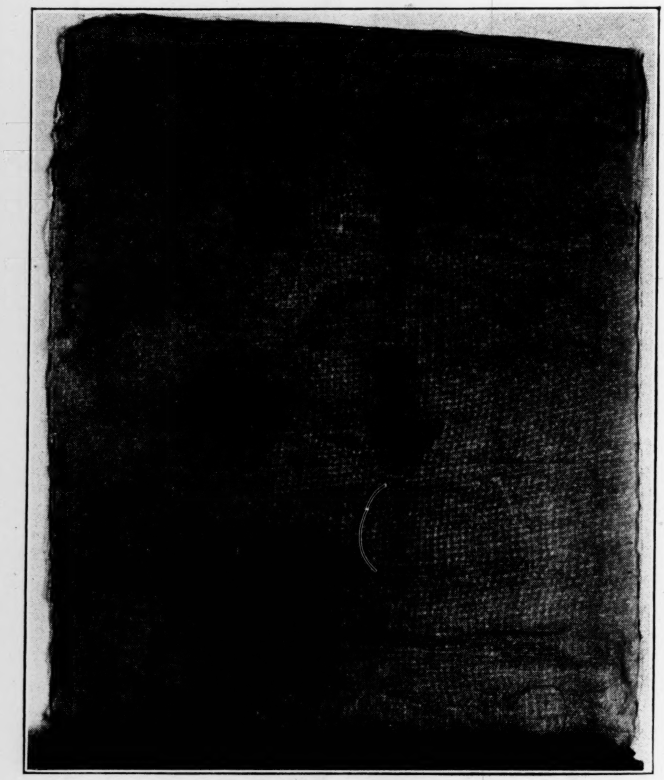


FIG. 4.—Photograph of 30 by 36-in. Specimen (98-per-cent Copper, 2-per-cent Tin Alloy) in Wood Frame No. 6; Returned from Portsmouth, Va., After 4 Years' Exposure Because of Failure of the Frame.

Although the three frames show corrosion and flaking, they are nevertheless considered to be in sound condition at the present time.

October 7, 1929.—
Screens Nos. 1 to 7 inclusive, no change since last report.
Screens Nos. 11 to 17 inclusive, no change since last report.
Screens Nos. 21 to 27 inclusive, destroyed by unknown person.

Chief Quartermaster offered to re-install screens Nos. 21 to 27 if the committee furnished the screens. It has not been decided to replace the set of screens Nos. 21

to 27 on 12 by 12-in. frames which were destroyed because they would be 4 years behind the other series. Then, too, the special frames are not available. Since the same materials are in two other kinds of 30 by 36-in frames the test is mostly intact.

IV. *Portsmouth, Va.:*

The three sets of specimens were exposed on the roof of the Lighthouse Depot, Bureau of Lighthouses, Portsmouth, Va., October 28, 1925. This depot is on the Portsmouth side of the Elizabeth River, opposite Norfolk. The atmospheric exposure of this test location is of the sea-coast type, although the atmosphere is contaminated at times by much smoke from tug boats and tankers which pull up beside the pier upon which the depot is built.

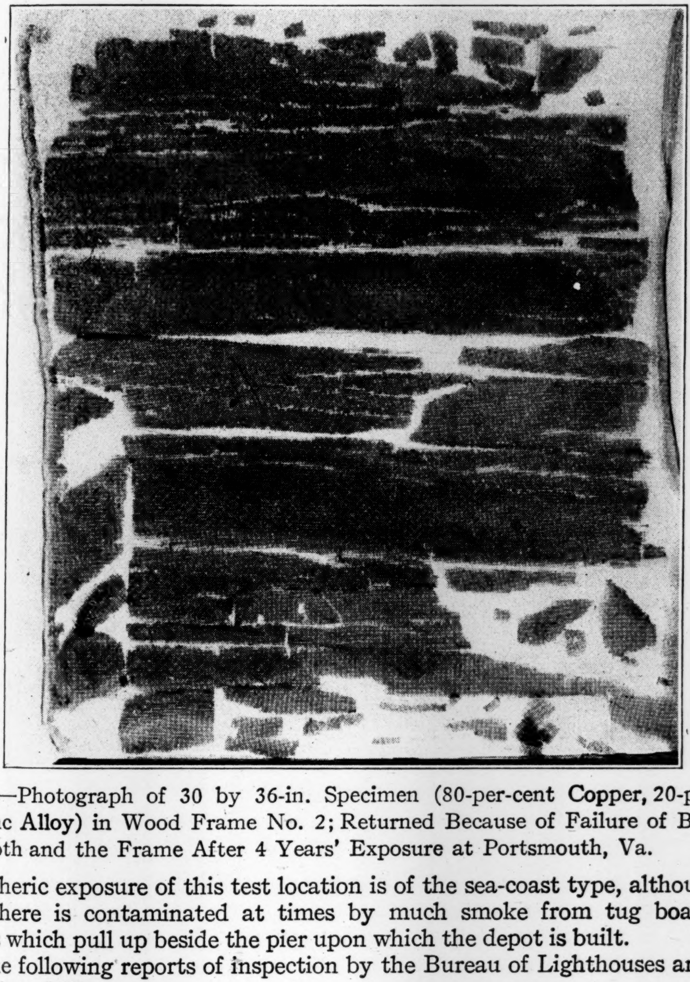


FIG. 5.—Photograph of 30 by 36-in. Specimen (80-per-cent Copper, 20-per-cent Zinc Alloy) in Wood Frame No. 2; Returned Because of Failure of Both the Cloth and the Frame After 4 Years' Exposure at Portsmouth, Va.

The following reports of inspection by the Bureau of Lighthouses are summarized as follows:

October 28, 1925.—Frames installed.

April 23, 1926.—Since installation, all specimens and frames are in good condition except all cloth has a white powder-like substance on them and this substance had lodged on the bottoms of all frames.

January 7, 1927.—No apparent change since the last report.

April 21, 1927.—No apparent change since the last report.

July 11, 1927.—No apparent change since the last report.

November 25, 1927.—No changes except little signs of deterioration of wood frames.

February 8, 1928.—All specimens in the same good condition except that the gulls have been roosting on top of some of the screens and Nos. 4, 11, 12, 13, 14, 15, 16 and 17 are spattered with excrement.

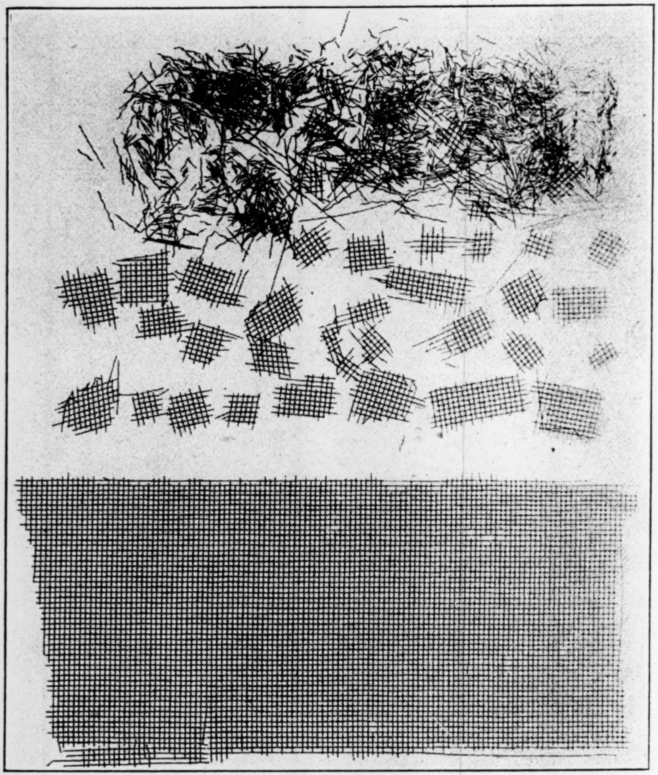
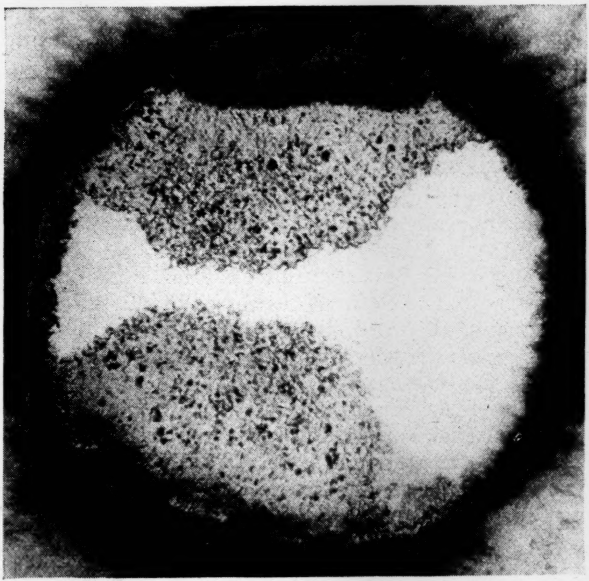


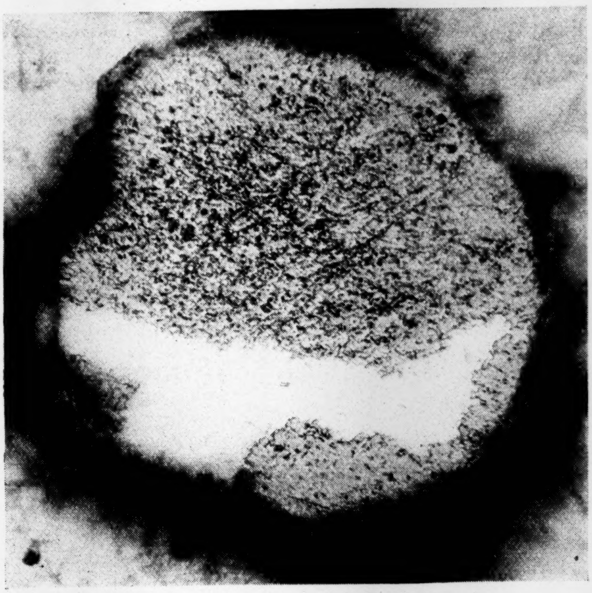
FIG. 6.—Photograph of Two Equal Areas of the 80-per-cent Copper, 20-per-cent Zinc Cloth; One piece has Been Crushed in the Bare Hand Two or Three Times to Show Extreme Brittleness Caused by 4 Years' Exposure at Portsmouth, Va.

April 17, 1929.—The copper wires stretched along the top of the frames as suggested by the committee was very effective and has entirely stopped the gulls from roosting over the frames. Wood frames again are showing some deterioration and will be retouched with paint promptly.

October 28, 1929.—Necessary to remove frames from roof, while building is re-roofed, to the roof of another building at the depot. In removing frames Nos. 2 and 6 they deteriorated badly and were shipped to the Bureau of Standards. The cloth in frame No. 2 failed badly.



(a) Cross-section of corroded alloy screen wire.



(b) Cross-section of corroded alloy screen wire.

FIG. 7.—Micrographs, Unetched, of Cross-Sections of (80-per-cent Copper, 20-per-cent Zinc) Alloy Screen Which Failed at Portsmouth, Va., After 4 Years' Exposure.

The wires were mounted in Rose's metal, which is shown in the micrographs as surrounding the more or less circular cross-sections of the wire. **The dark areas in the wire are the corroded portions** and the light areas the uncorroded portions.

In August, 1929, the author while on vacation near Portsmouth, inspected the screens and found that in some cases the identification marks were nearly obliterated and that the screens were not up in the order of the identification numbers. By a process of elimination the identification of all of the frames was established and the Bureau of Lighthouses advised accordingly.

The report of October 28, 1929, transmitted wood frames with screens Nos. 2 and 6, respectively, which failed when the sets were removed at the time the roof of the warehouse was repaired. Screen No. 6 which is of 98 per cent copper and 2 per cent tin was really removed because of the failure of the wood frame. Figure 4 is a photograph of this screen as received. Screen No. 2, which is of 80 per cent copper and 20 per cent zinc alloy, had failed badly; Fig. 5 shows the fragments as received. The cloth was extremely brittle, breaking easily in the hand on slight bending. Figure 6, shows an area of the cloth with the remaining pieces of another equal area which had been crushed two or three times in the bare hand to show the extreme brittleness.

Whereas, the original color of this material was a golden yellow, the fracture of the embrittled material was a reddish color which indicated de-zincification. Figure 7 (*a*) and (*b*) are micrographs (unetched, X 250) of the cross sections of two transverse wires. These show that the deterioration of the wires, apparently due to de-zincification, has penetrated deeply into the wire leaving only a small percentage of the virgin wire unaffected. The micrographs show that the penetration is not similar but varies from wire to wire; in some cases entering similarly from two sides and in other wires entering more deeply from one side. Contrary to what one might expect the penetration entered some of the wires from the face and back of the screen, whereas in others, it entered through a 90 deg. angle. In some wires, the remaining sound metal extends through the center of the section, in some others on one side, and in others in the center with the corroded area penetrating uniformly from the circumferences.

Further work of this type, as the investigation progresses, should be of interest in showing the deterioration of the different screen materials under the four conditions of atmospheric exposure.

REPORT OF COMMITTEE D-15

ON

THERMOMETERS

In 1928, Committee D-15 developed Tentative Specifications for Thermometers for Engler Viscosimeters (D 300 – 28 T).[1] At the time of their adoption these thermometers were believed to represent the best possible design to meet the dimensional requirements of the Engler instrument and the manner in which it is used for determining viscosity. However, numerous criticisms of the thermometer have been received, particularly on account of the large spherical bulb and the inconvenience of placing the thermometer in position for making the test. The thermometer was also less sensitive than desirable. The committee during the past year has given consideration to these criticisms and to the possibility of completely redesigning the instrument in order to overcome the objections which have been raised. As a result, the committee recommends that the Proposed Revised Tentative Specifications for Thermometers for Engler Viscosimeters, appended hereto,[2] be accepted for publication as tentative as a complete revision of the present Tentative Specifications D 300 – 28 T.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This recommendation has been submitted to letter ballot of the committee with the following results:

Item	Affirmative	Negative	Not Voting
REVISION OF TENTATIVE STANDARD Specifications for Thermometers for Engler Viscosimeters (D 300 – 28 T)..............	9	0	2

This report has been submitted to letter ballot of the committee, which consists of 11 members; 9 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

C. S. REEVE,
Secretary.

EDITORIAL NOTE

The proposed revision of the Tentative Specifications for Thermometers for Engler Viscosimeters was accepted. The specifications in their revised form appear on page 1257.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1108 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 773.

[2] See p. 1257.—ED.

REPORT OF COMMITTEE D-16

ON

SLATE

The committee has continued vigorously its investigations into the physical and chemical characteristics and utilization of slate. This it has done through its ten subcommittees which were organized during the year for their respective work. The committee held two meetings during the year: one in conjunction with the annual meeting of the Society, and the other with the annual convention of the National Slate Association in New York City on January 22, 1930. This mid-winter meeting of the committee has developed into the technical session of the National Slate Association and as such it has been of great value to all concerned and the means of attracting additional slate producers into the membership of the Society and an increasingly active participation by them in the committee's work. As an evidence of this the committee's membership now consists of 22 members, of whom 11 are classed as producers, an increase of 9 producer members during the past 2 years.

The 1929 report of the committee indicated that further study was necessary of the Tentative Method of Test for Water Absorption of Slate (D 221 - 27 T). Since this study is still in progress, and because the relation of the effects of drying on the strength and elasticity of slate has not been definitely determined, the committee deems it unwise at present to recommend the advancement of its tentative methods of tests to standards and accordingly recommends that the above tentative method and the Tentative Methods of Flexure Testing of Slate (Determination of Modulus of Rupture and Modulus of Elasticity) (D 222 - 27 T), and Test for Determining the Insulating Qualities of Slate (D 273 - 27 T) be continued as tentative.

ACTIVITIES OF SUBCOMMITTEES

Substantial progress is indicated by the following condensed reports of work in hand by the various subcommittees:

Subcommittee I on Methods of Tests (D. W. Kessler, chairman).—Previous studies of absorption of slate have indicated differences in results obtained by different laboratories when testing the same materials by the same procedure. The difficulty lies largely in the means of obtaining the dry weight of the specimens, hence a further program has been initiated to determine if lower drying temperatures can be satisfactorily used. The following laboratories are cooperating: Bell Telephone Laboratories, Rensselaer Polytechnic Institute, Lehigh University, Lafayette College, and the U. S. Bureau of Standards.

In general each laboratory received six test specimens of each particular slate by producers from Pennsylvania, Vermont and Maine, so selected that all of the 30 specimens of each slate were as nearly alike as it was possible for the producers to supply. Each group was divided into two minor groups of three specimens and a different procedure was followed on each. One of these called for drying successively at 120, 150, and 180° F., etc., to determine what temperature and drying period is necessary to drive off the free moisture and give reasonably constant weights. The other procedure to be employed on the remaining three specimens of each group is to immerse the specimens in water for two days without previous drying, weigh for the saturated weight and dry afterwards. It is assumed that this program will supply the following information:

1. The lowest feasible drying temperature;
2. Additional data on the effect of heat on slate as now employed for initial drying;
3. A comparison of the two methods;
4. Better information on the variations in results to be expected.

Results to date indicate that slate is a slow drying material and with some kinds there is an appreciable amount of moisture after several days of drying at temperatures below the boiling point of water. In some cases the difference in absorption obtained by drying a particular slate for two days at 150° F. and 24 hours at 230° F. is as much as 0.12 per cent, which is greater than the total absorption of some other slates. Conclusions in this should be deferred until all the results are available. On the whole, the results indicate that a satisfactory test procedure may soon be attained.

Subcommittee II on Abrasive Hardness (J. W. Ginder, chairman).—Progress of the work at the Bureau of Standards has been delayed due to the difficulty of developing machines for comparative tests when, for mechanical reasons, they will show a low percentage of abrasion on such materials as wood and linoleum. Measurements of actual wear of many materials in use on stairways, etc., are being made the subject of a later report.

Subcommittee III on Machining and Workability (Oliver Bowles, chairman).—An important function of this subcommittee is to bring to the attention of the committee any new and interesting developments in allied industries that may have an important bearing on the future of slate working methods and machinery. One of the most interesting of such recent events is the development of a new alloy known as tungsten carbide, which has remarkable hardness and cutting ability. The alloy is very expensive, costing about $500 a pound, but as it is comparable with the diamond in hardness, its wearing qualities are such that it may find economic use in the drilling and cutting of slate and other rocks.

Subcommittee IV on Electrical Slate (J. R. Brossman, chairman).—This subcommittee reports that tests have been made on slate and other slab materials (molded) in the usual recommended comparable and equal thickness as used in switchboard work and other phases of the electrical industry. These tests were conducted in the testing materials laboratory of the Massachusetts Institute of Technology by Mr. L. F. Woodruff, in July and August, 1929.

The specimens consisted of $1\frac{1}{2}$, $1\frac{1}{4}$, and 1-in. thick panels 33 by 24 in. in size. The tests were made on a Riehle testing machine, and all slabs were supported on 30-in centers, with a piece of 2 by 4-in. soft wood interposed between the slab and pressure head of the testing machine.

In general, these tests showed, on the recommended commercial comparable thickness, the slate to be more than three times as strong, and more than 23 times as stiff, and on equal thickness, twice as strong as the molded rock fiber.

The elastic limit of the molded material was reached at a little over 1000 lb. as indicated by the decided droop in the two curves. Above this force permanent yielding or setting of the material takes place. On the other hand, the deflection curve of the slate is perfectly straight up to the point of rupture, within the limits of experimental accuracy, indicating that the breaking strength and the elastic limit are the same.

The rigidity of the slate would be considered as a decided advantage, because the bolting of electric meters and other delicate mechanisms to a switchboard might result in considerable damage to them if later on the board should warp due to any cause.

Subcommittee V on Weathering Characteristics (Charles H. Behre, Jr., chairman).—The work of this subcommittee during the past year has concerned chiefly the changes in the colors of slate. In a large portion of our domestic slates these changes are slight and distributed through a long time-period. They may be sometimes advantageous or sometimes disadvantageous. The subcommittee has taken the view that the first thing to be done is to understand the nature of such changes and to measure their extent, leaving the question of their acceleration or prevention until more is known about causes.

1. The term "weathering," as employed by quarrymen and technical men, has several special meanings. Color changes of roofing slate are often desirable. It is recommended by the subcommittee that the term "color-aging" be considered as indicating the early color changes involved in the weathering of slate. This new term is suggested in response to the point made jointly by Messrs. L. E. Kern and W. H. Smith at the Easton meeting, in April, 1928, that weathering is not necessarily an undesirable feature.

2. In view of our lack of knowledge as to the cause and affect of color-aging of slates, the subcommittee recommends that any proposal for quick tests to determine the color-aging qualities of slates be tabled.

3. When slate is to be used for certain structural or roofing purposes, a color designation for the fresh slate more exact than any now in use is definitely needed. To this end the subcommittee on weathering is debating the adoption of a color nomenclature to apply to all slate.

4. The Subcommittee on Weathering Characteristics contemplates a conference between representatives of Committee D-16 and a subcommittee of the National Research Council to discuss the feasibility of preparing and perhaps of publishing a color chart especially applicable to slate.

5. For practical purposes, meanwhile the use of the already well-established name equivalents given in "Roofing Slate," Simplified Practice Recommendation No. R 14 – 28, of the U. S. Department of Commerce, is recommended; these names to designate the equivalent numbers on the modified Ridgway chart. This would make possible the retention of the terms, such as green, purple, etc., which now have a definite meaning to the producer. The numbers, however, might then also be used, as they are already basic to national and international color.

At the last meeting of CommitteeD-16 a paper by C. L. Lancaster and C. H. Behre, Jr., was presented as a part of this subcommittee's report which was of such interest that it is appended hereto.

Subcommittee IX on Utilization and Performance (R. S. Tibbals, chairman).—This subcommittee, organized a year ago, is investigating the applicability of the tentative methods of tests for water absorption, strength, and elasticity as applied to roofing slate. It is also investigating insulation and in cooperation with the U. S. Bureau of Standards is assembling specimens of slate long in use as roofing.

Since Subcommittee I has developed a method of test for determining the intrinsic strength of slate, this procedure should, in the opinion of Subcommittee IX, include provision for recording the actual breaking strength of the slate. This should be based, not upon the especially prepared sample provided for by the Tentative Methods of Flexure Testing of Slate (Determination of Modulus of Rupture and Modulus of Elasticity) (D 222 – 27 T) but upon the popular sizes of roofing slate, say 8 by 16 in., 10 by 18 in., and 11 by 22 in.

The need for such a test lies in the fact that slate in actual use is subjected to certain definite strains. Although peaked roofs are not built to be walked on, a certain amount of such usage is unavoidable. Wind pressure, too, subjects a slate roof to strains caused by sagging of the rafters and by vibration of the building. From a practical standpoint, therefore, information as to the actual breaking load of a slate shingle may be more valuable than its intrinsic strength. Theoretically, it should be possible to determine the breaking strength of any size slate from its modulus of rupture. Actually, there is reason to doubt whether this is true, since all roofing slate has a sheared edge which cuts down the thickness of the slate for half an inch or more at each edge.

(*a*) *Methods of Testing the Heat Insulating Qualities of a Slate Roof.* – With the attention of the home building public directed towards insulating materials by extensive publicity campaigns, the question arises as to the insulating qualities of slate and whether the use of some insulating material on the under side of the rafters to form a dead air chamber would better the performance of the slate roof.

The problem here is to know whether it would be to greater advantage to keep out the summer heat by the use of insulating materials or to allow it to escape through the natural conductivity of the slate. It is known that in certain hot countries stone floors are utilized in the houses in preference to wood. Therefore, without tests, it is not certain that the performance of slate would become more satisfactory if used in connection with dead air chambers and other means of insulation.

(*b*) *Performance of Slate Under Practical Conditions.*—It is under this heading that most of the work of this committee has been done during the past year. The committee has gathered slate from the roofs of some 15 buildings in the slate belt, first having made careful investigation as to the history of the roof in question. Over 50 samples of slate, ranging from 25 to 35 years old, marked for location and history of the slate, have been forwarded to the Bureau of Standards. Some 630 ft. of roofing has been removed from a development 12 years old, and also forwarded to the Bureau of Standards for examination.

While care is necessary to avoid duplication of effort, the excellent work being done by Subcommittee V on Weathering Characteristics, the performance of this slate in actual use would seem to come under the purview of this subcommittee and it is hoped that a full report may be given soon.

Subcommittee X on Standardization of Samples (C. W. MacDougall, chairman).—As the basic idea in all testing is to have the results of the test indicate the average performance of the material under certain conditions and as slate is a natural product, it must be expected that variations will extend over a wider range than would occur were the material a manufactured product, the composition of which may be controlled.

Due to the relationship of the cleavage planes to the ribbons or bedding planes of the slate, it is possible to obtain the slate in forms which are particularly desirable for certain purposes. From this it may be seen that the selection of the slate for all ordinary manufacture must be left entirely to the operators. However, specifications can be made for slate to satisfy certain requirements. The following is a summary of the recommendations of this subcommittee for samples and submissions:

(*a*) *Recommendations for Structural* (*Machined*) *Slate.*—

1. Only one test specimen to be taken from any one quarried block;

2. That the number of test specimens vary with the size of the order but never to be less than six;

3. That each specimen have clearly indicated on its surface in crayon the sample number and the direction of the grain;

4. That the producer furnish the testing laboratory with a statement showing the following: (1) the name of the company, (2) name of the quarry, (3) location of the quarry and, opposite the number of the specimen, (4) the date on which it was quarried and (5) the depth from which it was quarried. Same recommendations as above for absorption tests on structural slate;

5. These recommendations should apply to all slates which must be machined, including samples to be tested for electrical purposes, abrasive hardness, etc.

(*b*) *Recommendations for Roofing Slate.*—Methods of testing roofing slate should be investigated by Subcommittee I of Committee D-16 with the idea of setting up standards different from those specified for testing structural slate with the following recommendations:

1. That a standard size piece of prepared roofing slate (shingle) be used for testing; the specimen to be prepared by splitting and shearing in the same manner as the salable product is prepared;
2. That the specimen be not dried in an oven before testing;
3. That the recommended size be 10 by 18 by $\frac{3}{16}$ in.
4. That the grain of the slate in the specimen be parallel to the long axis of the specimen;
5. That only one specimen be taken from any bed in any particular block quarried;
6. That the number of specimens for test depend on the number of squares to be purchased but not to be less than six specimens to be chosen at random;
7. That each specimen be numbered and have the grain marked on the surface by crayon;
8. That the producer furnish to the testing laboratory a statement showing the following: (1) the name of the company, (2) name of the quarry, (3) location of the quarry. Specimens of roofing slate for absorption tests should be selected as above, cut to 6 by 6 in. and with edges then honed but with cleavage surface unchanged. Only one specimen for absorption should be sawed from any one shingle.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee, which consists of 22 members; 15 members returned their ballots, of whom 14 have voted affirmatively and 1 negatively.

Respectfully submitted on behalf of the committee,

WILLIAM B. PLANK,
Chairman.

D. KNICKERBACKER BOYD,
Secretary.

APPENDIX

CHEMICAL EXPERIMENTS ON ACID AND ALKALI RESISTANCE OF SLATES

By C. L. Lancaster[1] and C. H. Behre, Jr.[2]

Object.—The object of these experiments is to determine the effect of certain acids and alkalies on the mineral and chemical composition of slate, with an eye particularly to the color changes produced. Earlier studies, which these resemble, were carried on by Robert Notvest,[3] and by Dale and Hillebrand[4], but in Notvest's experiments the changes were carried considerably beyond those to be expected in the normal uses to which slate is put, and Dale's studies did not compare the color changes produced by different reagents.

Procedure.—It was decided to use accelerated tests, according to the well-accepted principle that natural "weathering" may be simulated by making up for the limited time available with increased strengths of the reagents. The acid and alkaline solutions used are, therefore, much stronger than the solutions to which the slate would ordinarily be exposed, though not as strong as those used by Notvest in his paper on "The Resistivity of Slate Against Acids and Alkalies."[3]

Slate specimens were cut to measure approximately 2 by 1 by 1 in. The specimens were heated at 110° C. for 24 hours, cooled in a desiccator ($CaCl_2$), and accurately weighed on analytical balances. They were then immersed in 0.1 *N* and 0.05 *N* solutions of the reagents indicated in Table I, the slate block being placed in an inclined position in a completely-closed glass vessel bearing the reagent; the specimens were supported by leaning them against the side of the container, so that they rested on the dihedral angle between one side and a small end of the slate block and on the corresponding dihedral angle at the other end of the specimen.

Samples were immersed for periods of 60, 120, and 180 days respectively. After immersion, each slate piece was removed, washed, heated to 110° C. for 24 hours, cooled in a desiccator and again accurately weighed, losses in weight being expressed in per cent. Results of these tests are given in Table I. Then the block was examined megascopically for discoloration and other surficial changes and laid aside for a petrographic study yet to be completed.

The solutions remaining after immersion were tested qualitatively for aluminum, lime, magnesium and iron, to obtain some idea as to which of these constituents had been chiefly attacked.

In all of the specimens immersed in HCl solutions, a fairly strong iron-staining was noted, especially on the darker layers. After immersion the liquid became yellowish; evidently the reaction begins with the formation of ferric chloride, and, upon the hydrolysis of this salt, ferric hydroxide is deposited on the slate surface. Pitting is also observed, being especially marked on the cleavage surface. The solution remaining after the immersion gave qualitative tests for iron, calcium and aluminum, and showed traces of magnesium in the cases where the stronger concentrations of acid were used.

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[1] University of Cincinnati, Cincinnati, Ohio.

[2] Asst. Prof. of Geology, Univ. of Cincinnati, and Associate Geologist, Pennsylvania Geological Survey.

[3] Robert Notvest, "The Resistivity of Slate Against Acids and Alkalies," privately published, Cleveland, 1925.

[4] T. N. Dale and Hillebrand and others, "Slate in the United States," U. S. Geological Survey, *Bulletin No. 586*, pp. 56 and 140, 1914.

In the specimens immersed in H_2SO_4, the changes are similar. With short immersions and dilute solutions, the surfaces become faintly pitted and encrusted with a white substance, presumably sulfates of calcium and aluminum. As the immersion period is lengthened, the pitting and the white substance become more marked, especially on the cleavage planes, and there is some iron-staining along the darker bands; however, the latter is not nearly as pronounced as when HCl is used. The remaining solution showed appreciable amounts of aluminum, calcium and iron, but gave no qualitative tests for magnesia. In this solution white crystals of calcium and aluminum sulfates formed on standing.

TABLE I.—RESULTS OF CHEMICAL EXPERIMENTS ON ACID AND ALKALI RESISTANCE OF SLATES.

Specimen	Reagent	Solution Strength	Days Immersed	Original Weight, g.	Final Weight, g.	Weight Lost, per cent
No. 1	H_2SO_4	0.1 Normal	60	91.0845	89.9642	1.22
No. 2	"	"	120	91.8918	90.5248	1.48
No. 3	"	"	180	91.2848	89.7728	1.65
No. 13	"	0.05 Normal	60	92.5674	92.1825	0.415
No. 14	"	"	120	91.3461	90.5046	0.925
No. 15	"	"	180	91.5078	91.0898	0.45
No. 4	HCl	0.1 Normal	60	91.1904	90.2839	1.01
No. 5	"	"	120	91.0003	90.0170	1.08
No. 6	"	"	180	90.9938	90.0018	1.10
No. 16	"	0.05 Normal	60	94.2211	93.7368	0.515
No. 17	"	"	120	90.8550	90.1553	0.77
No. 18	"	"	180	90.5596	89.8366	0.80
No. 7	NaOH	0.1 Normal	60	91.3948	91.3952	0.00
No. 8	"	"	120	91.1919	91.1809	0.01
No. 9	"	"	180	90.9243	90.9540	0.03
No. 19	"	0.05 Normal	60	90.5104	90.5039	0.007
No. 20	"	"	120	90.7500	90.7199	0.03
No. 21	"	"	180	91.2075	91.2020	0.007
No. 10	NH_4OH	0.1 Normal	60	91.3634	91.3621	0.001
No. 11	"	"	120	91.6319	91.6034	0.03
No. 12	"	"	180	91.3947	91.4641	0.07
No. 22	"	0.05 Normal	60	92.2069	92.2041	0.002
No. 23	"	"	120	90.7400	90.6985	0.046
No. 24	"	"	180	91.4947	91.4863	0.009

Aside from a slight pitting on the cleavage planes, the alkalies produced essentially no effects and color changes, especially, are conspicuously absent.

Conclusion.—So far as the tests have progressed, conclusions may be drawn as follows:

(*1*) Alkalies produce no marked "weathering" effects, and probably would not, even under different conditions short of very strong solutions, very high temperatures, or very long immersion or exposure; none of which are encountered in the use of slate for ordinary purposes.

(*2*) Hydrochloric and sulfuric acids act very slowly even when used in abnormally strong solutions, producing only a slight disintegration and discoloration. The color change consists of a delicate "rusting," especially of the more carbonaceous beds.

(*3*) From these results, it would seem that a further study of weathering effects should be directed especially at alterations produced by acids.

REPORT OF COMMITTEE D-17

ON

NAVAL STORES

The Committee on Naval Stores has been engaged during the past year in formulating methods for the examination of rosin to determine its suitability for each of its numerous uses and has prepared a draft of these methods. The proposed methods will be discussed at a meeting of the committee to be held during the annual meeting of the Society with a view to their publication as information for comment and criticism.

The Tentative Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark) (D 269 – 27 T) having been tentative for three years without revision is recommended to the Society for advancement to standard with the inclusion of a footnote reading as follows:

> For many uses of rosin the determination of dirt is not necessary. For those uses where dirt is important this method for its determination should be used.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

The recommendation appearing in this report has been submitted to letter ballot of the committee with the following result:

Item	Affirmative	Negative	Not Voting
TENTATIVE STANDARD ADVANCED TO STANDARD			
Tentative Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark) (D 269 – 27 T)	14	0	2

This report has been submitted to letter ballot of the committee, which consists of 16 members; 14 members returned their ballots, all of whom have voted affirmatively.

Respectfully submitted on behalf of the committee,

F. P. VEITCH,
Chairman.

C. F. SPEH,
Secretary.

EDITORIAL NOTE

The Tentative Method of Test for Determination of Toluol Insoluble Matter in Rosin (Chiefly Sand, Chips, Dirt and Bark) was approved at the annual meeting and subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appears in the 1930 Book of A.S.T.M. Standards, Part II, page 446.

REPORT OF COMMITTEE D-18

ON

NATURAL BUILDING STONES

During the past year no meetings of Committee D-18 have been held but the work of the committee that was in progress has been satisfactorily transacted by correspondence.

There have been several changes in the personnel of the committee during the year. The resignations of Messrs. C. T. Vandeveer, D. H. Johnson, C. P. Brewer and J. M. Bischoff were accepted and the following have been elected to membership: J. L. Mann replacing D. H. Johnson; Lee Huber replacing C. P. Brewer, and C. A. Daymude replacing J. M. Bischoff. The transfer of H. S. Brightly from a representative of the Indiana Limestone Co. to a representative of the Building Stone Assn. of Indiana, Inc., and the transfer of H. H. Dutton from a representative of the Indiana Limestone Co. to a personal membership was approved.

The following three proposed methods, appended hereto,[1] for conducting physical tests on building stone have now been approved by the committee and will be submitted to Committee E-10 on Standards at a meeting to be held after the annual meeting with the recommendation that they be approved as tentative standards:

Proposed Tentative Method of Compression Testing of Natural Building Stone;

Proposed Tentative Method of Flexure Testing of Natural Building Stone;

Proposed Tentative Methods of Test for Absorption and Apparent Specific Gravity of Natural Building Stone.

The submission of the above three methods for publication as tentative was submitted to letter ballot of the committee which consists of 18 members; 16 members have returned their ballots of whom 15 have voted affirmatively and none negatively.

In connection with the above methods of test, certain supplementary recommendations regarding the selection, size and shape of samples of stone for testing and the manner in which these samples are to be cut up for test specimens, also the several types and number of test specimens to be prepared therefrom have been developed in a preliminary form for study and consideration by the committee.

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[1] See pp. 1161 to 1168.—Ed.

The first installment of Proposed Definitions of Terms Relating to Natural Building Stone applying to the work of Committee D-18 and used in the building stone and related industries is appended hereto as information.

The bibliography of existing data mentioned in last year's report[1] has been completed and three of the various sections of this bibliography have been sent to the different branches of the industry for comment, study and supplementary recommendations.

Additional data on uniform methods of cubing stone has been prepared by Subcommittee IV on Uniform Cubing of Stone and has been submitted to the committee for consideration.

A schedule of surface finishes and their descriptions has been prepared by Subcommittee V on Surface Fnishes following the preliminary discussion of this subject at the last meeting of the committee and this has now been submitted to the committee for further consideration. It is hoped that this material can shortly be worked into final form for submission to the Society.

The election of officers resulted in the selection of the present incumbents for the ensuing term of two years.

This report has been submitted to letter ballot of the committee which consists of 18 members; 16 members returned their ballots of whom 15 have voted affirmatively and none negatively.

Respectfully submitted on behalf of the committee,

F. Y. JOANNES,
Chairman.

H. S. BRIGHTLY,
Secretary.

EDITORIAL NOTE

The Tentative Methods of Compression Testing of Natural Building Stone, of Flexure Testing of Natural Building Stone, and Tests for Absorption and Apparent Specific Gravity of Natural Building Stone, referred to in the report, were subsequently approved on August 12 for publication as tentative by Committee E-10 on Standards and appear on pages 1161, 1164 and 1167.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 484 (1929).

APPENDIX

PROPOSED DEFINITIONS OF TERMS RELATING TO NATURAL BUILDING STONE

In preparing these definitions care has been taken to avoid including technical details of geology and mineralogy not essential to commercial usage.

Stone.—Any natural rock deposit or formation of igneous, sedimentary and/or metamorphic origin, either in its original or altered form.

Building Stone.—The quarried product of any natural rock deposit, or formation previously defined as "stone" (other than crushed or broken stone used as an aggregate) which, by reason of its physical and chemical properties, esthetic characteristics and resistance to deterioration upon exposure to weathering, is suitable for structural and ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character (see Explanatory Note, page 896.).

NOTE.—The above definition is not intended to cover or provide for certain marbles or other stones used especially for interior decoration.

Granite.—Any natural igneous rock formation of visibly crystalline texture.

NOTE.—For commercial purposes the gneisses and schists suitable for building usage, are included under the general classification as granite under this definition.

Building Granite.—The quarried product of any natural rock formation previously defined as "granite" (other than crushed or broken granite used as an aggregate), which, by reason of its physical and chemical properties, its working properties, esthetic characteristics and resistance to deterioration upon exposure to weathering, is suitable for structural and ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character.

Basalt.—Any volcanic rock of micro-crystalline or amorphous texture, dark color and high true specific gravity, including porous or vesicular basalt which by reason of its structure has a low apparent specific gravity.

Limestone.—Any natural rock of sedimentary origin composed principally of calcium carbonate or of calcium and magnesium carbonates in either its original chemical or fragmental, or recrystallized form.

Building Limestone.—The quarried product of any natural rock deposit or formation previously defined as limestone (other than crushed or broken limestone used as an aggregate) which, by reason of its physical and chemical properties, its working properties, esthetic characteristics and resistance to deterioration upon exposure to weathering, is suitable for structural or ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character.

Oolitic Limestone.—A variety of limestone quarried principally for building purposes, which is primarily a calcareous-sand rock formation, composed largely of shells and shell fragments. (See definitions of *Limestone* and *Building Limestone.*)

Dolomite.—A magnesium limestone, composed essentially of the mineral dolomite, a double carbonate of calcium and magnesium. (See definitions of *Limestone* and *Building Limestone.*)

Marble.—Any crystalline or micro-crystalline natural rock deposit of sedimentary origin composed principally of calcium carbonate or calcium and magnesium carbonates, or serpentine, the crystalline character of which has reached the stage which permits it to take a polish. This classification includes also those serpentines that are of igneous origin as well as those of sedimentary origin.

Building Marble.—The quarried product of any natural rock deposit or formation previously defined as marble (other than crushed or broken marble used as an aggregate) which, by reason of its physical and chemical properties, its working properties, esthetic characteristics and resistance to deterioration upon exposure to weathering, is suitable for structural or ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character.

Decorative Marble.—The quarried product of any natural rock deposit or formation previously defined as marble which, by reason of its coloring and marking, or its physical properties, or both, is suited more particularly for interior decorative purposes, including also those natural stones not strictly marble, such as serpentine and the semi-crystalline fossilferious or so-called "fancy" limestones, that will take a high polish are applicable for and are used principally for purposes of interior decoration.

Dolomite Marble (A Magnesium Marble).—See definitions of *Dolomite, Marble, Building Marble, Decorative Marble.*

Sandstone.—Any natural rock of sedimentary origin composed primarily of silica or silicate grains, compacted or cemented together in any way by nature.

Quartzite.—Any quartz sandstone thoroughly cemented by silica or indurated by recrystallization.

NOTE.—This definition includes also "semi-quartzite."

Building Sandstone.—The quarried product of any natural sandstone or quartzite deposit previously defined as "sandstone" or "quartzite" (other than crushed or broken sandstone used as an aggregate) which, by reason of its physical and chemical properties, its working properties, esthetic characteristics, and resistance to deterioration upon exposure to weathering, is suitable for structural or ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character.

Building Slate or Argillite.—Any thoroughly compacted and indurated natural shale deposit capable of being quarried in layers or blocks for building use, which, by reason of its physical and chemical properties, esthetic characteristics and resistance to deterioration upon exposure to weathering, is suitable for structural or ornamental purposes in the exterior of buildings and other structures of either architectural, memorial or engineering character.

Igneous Rock.—Any rock of Plutonic or volcanic origin.

Volcanic Rock.—Any igneous rock of micro-crystalline or amorphous texture.

NOTE.—This includes rhyolite, andesite, basalt.

Sedimentary Rock.—Any rock formed by the deposition of particles from water whether from matter held in suspension or from the crystallization or coagulation of matter held in solution.

Metamorphic Rock.—Any rock formation which, in the natural ledge, has undergone marked change in micro-structure and/or character due to heat, pressure or moisture or a combination of these agencies of nature and thus exists in a form different from its original form.

Trap Rock.—An indefinite term, often applied to basalt and other volcanic rocks of micro-crystalline texture, but sometimes also applied to certain kinds of semi-metamorphic sedimentary rock and therefore is not considered a term which can be suitably defined for technical purposes.

EXPLANATORY NOTE

The terms "structural," "ornamental," "decorative," "architectural," "memorial" and "engineering" as employed in the foregoing definitions are explanatory rather than definitive and are used to designate what may be somewhat broadly defined as follows:

Structural.—A material and/or system of construction capable of safely supporting loads in addition to its own weight and resist stresses imposed by external agencies, within the limits of the safe working properties specified for that kind or grade of material and/or system of construction, as the result of properly conducted tests.

Ornamental.—A material and/or method of use, capable of employment for the finished exteriors of building structures that is durable and capable of resisting the action of the elements in a satisfactory manner when so exposed, without deterioration that in any way seriously impairs its suitability for the finished exterior of so-called permanent building structures.

Decorative.—A material and/or method of use intended primarily for decorative purposes, in which structural value for the support of loads or resistance to stress and ornamental value from the standpoint of resistance to weather action in exposed exterior locations are not essential characteristics.

Architectural.—Building structures of all kinds which enclose interiors that are utilized for some specific purposes in the activities of human life, administrative, educational, religious, institutional, commercial and industrial, recreational and habitational.

Memorial.—Ornamental structures of all kinds in which the enclosed interiors, where present, are generally of minor importance and not customarily used to house the activities of human life, including monuments, mausoleums and memorial structures, fountains, arches, gateways, bandstands and other structural landscape embellishments, other than structures of so-called engineering types.

NOTE.—The term memorial as thus defined will of course include many structures of architectural character, which, for sake of convenience in the work of this committee, are embraced under the memorial classification.

Engineering.—Structures of all kinds devised to perform some important function other than the housing of human activity, such as bridges and culverts, viaducts, aquaducts, dams, street and parkway systems.

REPORT OF COMMITTEE E-1
ON
METHODS OF TESTING

The past year in the work of Committee E-1 has seen considerable activity on the part of its technical committees and sections, organized to consider specific types of test. Additional committees have been organized, such as the Technical Committee on Thickness Measurement, under the chairmanship of W. E. Emley, and Sections, of the Technical Committee on Mechanical Testing, on Elastic Strength of Materials, under the chairmanship of F. B. Seely, and on Effect of Speed of Testing, under the chairmanship of J. Hammond Smith. The Committee on Impact Testing has been reorganized, under the chairmanship of J. M. Lessells, as a Section of the Technical Committee on Mechanical Testing and has already made an excellent start on the work before it in the preparation of a résumé of progress in impact testing since the Symposium on Impact Testing held in 1922. A further Technical Committee on Freezing-and-Thawing Tests has been authorized.

Of outstanding significance is the organization, during the year, of a Technical Committee on Presentation of Data. This is an outgrowth of certain discussions at the 1929 annual meeting on the use of statistical methods in studying data which in itself resulted in the holding of a round-table discussion in conjunction with the American Society of Mechanical Engineers in December. The interest shown in this general subject and the need for cooperative effort in further studying the uses and applications of statistical methods prompted Committee E-1 to undertake this work in so far as it applies to methods of testing. The technical committee was organized in March, with W. A. Shewhart as chairman and A. E. R. Westman as secretary. As the work of this committee progresses, it will include the subject of sampling methods and size and number of samples, which is of particular significance in practically all specification work. Further discussion of the committee's program is given later in this report.

Some changes in personnel have taken place as, for example, the appointment by the Executive Committee of W. L. Sturtevant to fill the vacancy on the Advisory Committee due to the resignation of A. T. Goldbeck. Mr. J. P. Hubbell has found it necessary to relinquish the chairmanship of the Technical Committee on Size and Shape and

Mr. L. T. Work has been appointed to take over the work of this committee.

Index to Methods of Testing.—Committee E-1 has again issued in mimeographed form a complete Index to the methods of test of the Society. One of the functions of the committee is to correlate the various methods as developed by the several standing committees, eliminating duplications of procedures where possible, and unifying the various descriptions of a given method of test. The Index is of considerable assistance in this connection since it not only makes evident where more than one procedure for the same determination appears in the Society's standards, but also keeps the standing committees advised as to where the various procedures that have already been prepared may be found, which frequently may be of considerable assistance when a standing committee has in mind the development of a new method of test. It is planned to issue a revised Index during the next few months, which will again be furnished to the representatives of standing committees serving on Committee E-1 and to committee officers, and to other members of the Society on request. That the preparation of this Index is well worth while is evidenced by the number of requests received for it each year.

ACTIVITIES OF SUBCOMMITTEES

As indicated above, all of the technical committees, organized either for the study of specific methods of test from a fundamental standpoint, or for the correlation of methods, have been quite active during the year. The progress made by these several technical committees is set forth below.

Technical Committee on Mechanical Testing (H. F. Moore, chairman):

The activities of the technical committee have been confined to the action of the sections which are carrying on its work. No work has been brought to the stage where new tentative methods are being proposed, although several methods are in immediate prospect.

The technical committee is, however, recommending the advancement to standard of the tentative definitions of the terms "stress," "strain," "stress-strain diagram," "tensile strength," "compressive strength," and "modulus of elasticity" appearing in the Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 25 T),[1] subject to the approval of Committee E-8 on Nomenclature and Definitions.

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[1] *Proceedings,* Am. Soc. Testing Mats., Vol. 25, Part I, p. 879 (1925); also 1929 Book of A.S.T.M. Tentative Standards, p. 794.

Section on Tension Testing.—This section, under the chairmanship of R. L. Templin, has conducted a questionnaire which was sent to some 200 firms and individuals in an effort to obtain a survey of the detailed testing procedures and apparatus used in making tension tests of metals. Replies indicate quite a diversity of practice both in procedure and apparatus used. They will be correlated and analyzed and, based on this survey, the section will proceed to develop a procedure to be followed in the tension testing of metals, which will be submitted in due course as a tentative standard of the Society as a modification of the present Tentative Methods E 8 – 27 T. The results of an investigation carried out in the chairman's laboratory on "A Comparison of the Sheet Tensile Test Specimen Proposed by the International Commission for Air Navigation and the Tentative A.S.T.M. Standard" will be made available to the section.

The section also proposes to consider test procedures for nonmetallic materials.

Section on Compression Testing.—The Section on Compression Testing, under the chairmanship of W. A. Slater, has completed organization and plans to hold a meeting in connection with the annual meeting of the Society to plan its work for the coming year.

Section on Bend Tests for Ductility.—The section, under the chairmanship of A. B. Kinzel, submitted with its report last year a Proposed Method of Quantitative Bend Testing. This has been brought to the attention of all the standing committees of the Society and has been further reviewed during the past year by the section in the light of criticisms received. The committee expects to be in a position to submit the proposed method in the near future for publication as tentative. It appears as Appendix I to this report for publication as information.

The committee proposes to make a review of the present specifications of the Society to show what the equivalent requirements should be if the bend tests were made in accordance with the proposed method.

Section on Indentation Hardness.—This section, under the chairmanship of J. R. Townsend, has prepared a first draft of a proposed procedure in making Rockwell hardness tests. Since a patented instrument is involved, certain features of this procedure are now receiving the attention of the Executive Committee of the Society.

Section on Impact Testing.—This section, under the chairmanship of J. M. Lessells, is a reorganization of the former technical committee on impact testing. The section is cooperating with a similar committee organized by the American Society of Mechanical Engineers, for research on impact testing. The committee has prepared a résumé of the progress made in the impact test since the Symposium on Impact Testing held at the annual meeting of the Society in 1922. The résumé appears as Appendix II to this report.

Section on Effect of Speed of Testing.—The section, under the chairmanship of J. Hammond Smith, has held several meetings during the year. A general discussion of the problem has developed the necessity of having some better measure of testing speed than the speed of head of the testing machine. The advantages and difficulties of controlling the rate of application of load have been considered as has also the possibility of controlling the rate of strain. Plans have been made for a series of tests to show the effect of these variables for a wide range of materials.

Section on Elastic Strength of Materials.—This section, under the chairmanship of F. B. Seely, has been organized during the year. At a meeting of the committee a proposed outline for nomenclature was developed. Considerable progress has been made in considering the various aspects of elastic strength determinations and it is expected that the committee will have a number of proposals to present during the year.

Technical Committee on Consistency, Plasticity, Etc. (E. C. Bingham, chairman):

The committee has been cooperating with the Society of Rheology in the development of suitable standards for viscosity. A committee has been appointed by that society to review the data used in arriving at the present published values for the viscosity of water, to see whether some agreement cannot be reached or whether a new determination of the viscosity of water is desirable. It is, of course, important that there should be a uniform basic standard. It is probable that, when the viscosity of water is agreed upon, other supplementary standards with more viscous liquids will be established.

The committee has been cooperating with various industrial laboratories in order to obtain instruments which will give the consistencies of very viscous materials such as rosin, asphalt, etc., in absolute units. Plasticimeters are now in use to measure the flow or consistency of such materials and possibly of materials of even greater consistency, such as lead, tin, etc.

Before making a critical review of the Society's methods covering various determinations of consistency and related properties, it is necessary to establish definitions. The committee has been at work for several years on the development of such definitions and it is expected that the committee will be prepared to recommend in the near future definitions for consistency and plasticity for publication as tentative. The following are now serving as a basis for discussion in the committee:

Consistency is that property of a material by which it resists permanent change of shape and is defined by the complete flow-force relation. If in non-turbulent flow the ratio of flow to force is constant, the material is said to be fluid, otherwise it is plastic.

Plasticity is that property of a material by which, as the shearing stress is lowered, the material resists change of shape relatively more than in the case of a fluid; thus for a plastic material the ratio of flow to force is not constant.

Technical Committee on Size and Shape:

The Technical Committee on Size and Shape, which has been under the chairmanship of J. P. Hubbell, has several assignments before it. One is the study of material of sub-sieve sizes, which has been under the jurisdiction of a separate section on this subject as discussed below. It has also been considering the methods of reporting results of sieve analyses. Several methods are now in use, in some instances the results being reported cumulative and others non-cumulative. In certain tests the order of the sieves is from fine to coarse and in others from coarse to fine. The committee is endeavoring to arrive at some uniformity in expressing results and particularly is attempting to develop recommendations which will insure the results being reported so as to make it possible to reproduce the complete sieve analysis, which is not always the case with the present methods of reporting.

One section of the committee still has before it the development of tolerances for round-hole screens. This is an outgrowth of considerations the committee had been giving to the possibility of fixing upon either the round-hole screen or the square-mesh screen in making analyses of coarse materials.

Section on Sub-Sieve Sizes (G. S. Haslam, chairman).—This section has developed methods of procedure for particle size determination. Several alternate methods are included. These methods represent a considerable amount of cooperative work on the part of the members of the section in which various methods were tried out in the cooperating laboratories, using samples of a number of different materials.

The methods appear in Appendix III to this report as information. Criticisms are solicited so that the methods may be reviewed in the light of these and submitted for publication as tentative a year hence.

Technical Committee on Methods for Density (A. T. Goldbeck, chairman):

The Technical Committee on Methods for Density is drawing up a statement of precautions to be taken in performing the various kinds of tests for specific gravity. The various portions of this work are being assigned to the individual members for development, with the thought in mind that a complete statement may be presented in 1931. The various procedures in the Society's standards will then be reviewed to develop whether they are complete, including the various precautions that may be necessary in each individual test.

The committee has reviewed the present Standard Definitions of Terms Relating to Specific Gravity (E 12 – 27) and is making several recommendations to Committee E-8 on Nomenclature and Definitions for minor modifications in these definitions.

The committee reviewed during the year proof sheets issued by the American Society of Mechanical Engineers covering Density Determinations: Instruments and Apparatus, comprising Part 16 of the A.S.M.E. Power Test Code, and as a result of this review transmitted a number of comments to that society for its consideration.

Technical Committee on Volatility (C. S. Reeve, chairman):

In 1927, through the activity of Committee E-1, a new short-necked distillation flask was adopted by Committees D-4 on Road and Paving Materials and D-7 on Timber, for the distillation of bituminous road materials and creosote oil, respectively. The flask has since been adopted by the American Wood Preservers' Association and American Railway Engineering Association for the distillation test of creosote oil. Two years' experience in the use of the flask has demonstrated the advisability of improving the specifications for this flask in order to make the application of the specifications more practical and in closer accord with the flasks which have been regularly produced and used. The following proposed requirements were therefore presented to Committees D-4 and D-7 and accepted by them for a revision of the specifications as they appear in the Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 28 T) and in the Standard Method of Test for Distillation of Creosote Oil (D 246 – 28):

	EXISTING REQUIREMENTS	PROPOSED REQUIREMENTS
Diameter of Bulb, outside	86 mm. ± 1.5 mm.	86.0 mm. ± 1.5 mm.
Diameter of Neck, inside	22 mm. ± 1.0 mm.	22.0 mm. ± 1.0 mm.
Diameter of Tubulature, inside	10.0 mm. ± 0.5 mm.	10.0 mm. ± 0.5 mm.
Length of Neck	43 mm. ± 1.0 mm.	....

	EXISTING REQUIREMENTS	PROPOSED REQUIREMENTS
Height of Flask, outside		131.0 mm. ± 1.5 mm.
Distance, Top of Neck to Tubulature	25 mm. ± 1.0 mm.	
Vertical Distance, Bottom of Bulb Outside to Horizontal Tangent at Tubulature, inside		93.0 mm. ± 1.5 mm.
Length of Tubulature	220 mm. ± 5.0 mm.	220 mm. ± 5 mm.
Angle of Tubulature	73 deg. ± 1 deg.	73 deg. ± 2 deg.
Thickness of Tubulature Wall	0.8 to 1.2 mm.	1.0 to 1.5 mm.

The revision contemplates no change in the flask now in use but principally replaces, with more definite dimensions, two objectionable requirements, namely, length of neck and distance from top of neck to tubulature, which cannot be definitely measured since they are taken to some point on a curved surface.

The Section on Distillation of Committee D-4 is actively engaged in the development of a test method involving the use of this flask for testing cut-back asphalt products.

It has been appreciated for some time that the Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 – 27) was inadequately described and not strictly in accord with the practice being followed. During the past year Committee D-4 has given attention to the matter and as a result has adopted a revision of the test which more clearly covers its intent without in any way altering the practice which has been followed with the method as at present published. In view of the appearance of the new Book of Standards, Committee D-4 will ask for authority to substitute the proposed revision for the present standard method. The possible need for amendment or reinforcement of the Test for Flash and Fire Point by Means of Open Cup (D 92 – 24) to care for the testing of cut-back and high-softening-point asphalts has been considered by Committees D-2 on Petroleum Products and Lubricants, D-4 on Road and Paving Materials, and D-8 on Bituminous Waterproofing and Roofing Materials and, with the approval of the other two, Committee D-2 has assumed the task of determining what, if any, amendments are necessary.

Committee E-1 asks that the revisions being recommended in these several standards by the standing committees concerned be approved.

Technical Committee on Chemical Composition (G. E. F. Lundell, chairman):

The Technical Committee on Chemical Composition again asks that all methods of chemical analysis developed by the standing committees be submitted to the technical committee for comment prior to their submission to the Society for publication as tentative.

Technical Committee on Thickness Measurement (W. E. Emley, chairman):

This technical committee has now completed its organization, having added eight manufacturers of micrometer gages as advisory members in addition to the regular members originally appointed. A careful survey of present specifications, prepared at the Society headquarters, shows that if a commercial testing laboratory is equipped to test all kinds of materials in accordance with the Society's specifications it must have 25 different micrometer gages to measure thickness. These gages differ from each other chiefly in the area of the presser foot and the load applied to the presser foot.

All materials are more or less compressible; therefore the thickness, as measured by means of a micrometer gage, varies more or less with the pressure applied by that gage. With certain materials as, for example, sheet metal, it may be that this variation of thickness with pressure is insignificant within the limits of pressure ordinarily applied in measuring thickness; with other materials, such as soft rubber, and many kinds of textile fabrics, this factor is decidedly significant and the pressure used in making a thickness measurement should be given due consideration.

It would seem that a standard pressure could be adopted for use in measuring the thickness of all materials whenever a micrometer gage is used. The committee is now investigating the feasibility of adopting such a standard pressure.

Technical Committee on Presentation of Data (W. A. Shewhart, chairman):

Reference has been made earlier in this report to the organization of a new technical committee on presentation of data. An organization meeting of this committee was held in March at Detroit, at which the immediate work of the committee was planned. The committee has in mind presenting some of the fundamental physical concepts underlying the modern statistical theory of measurement, and arranging for the presentation of a series of papers and discussions at its meetings.

Since all physical measurements are statistical in nature, the committee will give consideration to the application of statistical theory in the planning of research programs in respect to such points as:

1. Most efficient method of measuring a quantity when the measurements are subject to error.
2. How many measurements shall be taken.
3. How to correct observed data for errors of measurement.
4. How to determine when the variability in a set of data is greater than should be left to chance.

Since the specifications often involve sampling schemes, the committee will consider the problem of setting forth principles upon which simple procedures should be based. Some specific points to be considered are:

1. How shall a representative sample be selected?
2. How large a sample shall be taken?

Editorial Committee:

In addition to developing the Index to Methods of Testing, the Editorial Committee has continued its review of miscellaneous methods of test. This review, however, has not progressed to the point of making any recommendations on the approval of these methods other than to recommend the approval of the Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 28) under the jurisdiction of Committee A-6 on Magnetic Analysis. These methods seem to be in satisfactory form and were originally approved in 1924 by Committee E-1. They were revised in 1928, however, and Committee E-1 accordingly recommends the approval of the revised methods.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
1. Approval of Advancement to Standard of Definition of Stress, Strain, Stress-Strain, Diagram, Tensile Strength, Compressive Strength and Modulus of Elasticity, appearing in Tentative Definitions of Terms Relating to Methods of Testing (E 6 – 25 T)	28	0	9
2. Approval of Revisions of Tentative Method of Test for Distillation of Bituminous Materials Suitable for Road Treatment (D 20 – 28 T)	19	0	18
3. Approval of Revisions of Standard Method of Test for Distillation of Creosote Oil (D 246 – 28)	17	0	20
4. Approval of Revision of Standard Method of Test for Loss on Heating of Oil and Asphaltic Compounds (D 6 – 27)	19	0	18
5. Approval of Revision of Standard Methods of Test for Magnetic Properties of Iron and Steel (A 34 – 28)	22	0	15

This report has been submitted to letter ballot of the committee, which consists of 48 members; 32 members returned their ballots, with the following results: Advisory Committee, 6 affirmative and none negative; Standing Committees, 26 affirmative and none negative.

Respectfully submitted on behalf of the committee,

W. H. FULWEILER,
Chairman.

R. E. HESS,
Ex-Officio Secretary.

EDITORIAL NOTE

The tentative definitions of the terms stress, strain, stress-strain diagram, tensile strength, compressive strength and modulus of elasticity appearing in the Tentative Definitions of Terms Relating to Methods of Testing were approved at the annual meeting and were subsequently adopted as standard by letter ballot of the Society on September 2, 1930, and appear in the 1930 Book of A.S.T.M. Standards, Parts I and II, pages 932 and 1134, respectively.

APPENDIX I

PROPOSED METHOD OF QUANTITATIVE BEND TESTING[1]

1. *Scope.*—This method of quantitative bend testing consists essentially in bending the specimen by means of forces at the ends and without introducing additional forces at the point of maximum bending. This is followed by measurements of the elongation of the outside fibers at the point of maximum bending. This is known as free bend with measurement of the fiber elongation.

Note.—Although most of the work with this test has been carried out on iron and steel, sufficient work has been done with hardened copper and other non-ferrous metals to show that it is entirely applicable. It is obvious that if the specimen bends flat upon itself without fracture no quantitative data in addition to this fact may be obtained. Work on producing failure in such highly ductile materials by special means is under way, and recommendations may be made at a subsequent date.

Test Specimen

2. *Preparation of Test Specimens.*—(*a*) For quantitative results in which the measured performance is independent of the thickness of the specimen, rectangular specimens with widths at least three times the thickness shall be used. The edges shall be smoothed so that the fracture does not take place at the edge. A radius up to one-eighth the thickness of the specimen may be used on the edges. The outside surfaces of the specimen shall be smooth and free from local defects and transverse scratches. The length may vary with the thickness of the piece and is unimportant provided it is long enough to perform the bending operation.

(*b*) Round bars may be tested by this method but the results will only be comparative, as for the same material the fiber elongation is found to vary slightly with the diameter.

(*c*) The gage length in which the elongation is measured shall be 0.3 in. in the case of plate from $\frac{1}{4}$ to $\frac{1}{2}$ in. in thickness and 1 in. for all plates over $\frac{1}{2}$ in. in thickness. This gage length shall be located at the section of maximum bending and in the center third of the width of the specimen.

Note.—For certain special applications such as welds it may be desirable to use other gage lengths. In such cases, the gage length used shall be at least equal to the thickness of the plate and not more than twice the thickness of the plate but shall in no case be more than 1 in.

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[1] Criticisms of this Proposed Method are solicited and should be directed to Mr. A. B. Kinzel, chairman of the Section on Bend Tests for Ductility of the Technical Committee on Mechanical Testing, of Committee E-1 on Methods of Testing, Union Carbide and Carbon Research Laboratories, Inc., Long Island City, N. Y.

PROCEDURE

3. *Method of Starting the Bend.*—In order to start the bend any local stress or strain at the point which eventually will have the greatest bending should be avoided. This may be accomplished by holding the specimen in a vise about one-third from the end, producing an initial bend at this point by hammer blows, or the specimen may be set up on cross supports and the initial bend started by compression at the third points. The initial bend shall be far enough from the final point of maximum bending so as not to affect it. This shall be performed on both ends of the specimen.

4. *Method of Closing the Bend.*—(*a*) The specimen with initial bends on each end shall be placed in a vise or press as a strut and compression applied at the ends. The vise or press shall be closed until failure of the outside fibers occurs. The speed is not a factor provided actual shock is avoided. The continuity of closing and the speed may be varied at will without affecting the results within the limits of accuracy specified in Section 6.

(*b*) Bending may be carried out in special machines by any other suitable means provided that local stresses at the point of maximum bending are avoided. If such stresses are not avoided low values will result.

5. *Measurement of Fiber Elongation.*—(*a*) The performance of the specimen in the bend test shall be evaluated by the measurement of the outside fiber elongation. The most direct method of performing this is to measure with a flexible scale the final length between gage marks placed on the specimen before bending.

(*b*) Any other method of measuring the fiber elongation which gives the same values as this direct method may be used. For example, in some cases it may be objectionable to put gage marks on the specimen. In this event the radius of the outside of the specimen may be measured and the elongation calculated. For simplified operation a bend extensometer has been developed which reads fiber elongation directly when placed on the curved surface. Any such method is satisfactory if, as above stated, the values obtained are consistent with the method of direct measurement.

NOTE.—With material less than ¼ in. in thickness the difficulties in measurement of elongation are so great that the committee is not yet prepared to make any recommendations. The committee is continuing the study of this problem and hopes to make recommendations at a future date.

6. *Accuracy.*—The accuracy of the test results as obtained by this procedure shall be at least 5 per cent of the fiber elongation.

APPENDIX II

RÉSUMÉ OF PRESENT STATUS OF THE IMPACT TEST

The following is a résumé of work carried out on the impact test since the Symposium on Impact Testing of Material held in 1922[1] by the Society. The résumé is divided into two parts: (1) metals, and (2) non-metals.

METALS

The increase in the severity to which materials are now subjected makes the engineer have more and more interest in dynamic forms of testing. Much work has been done in this country by H. F. Moore[2], R. R. Moore,[3] H. W. Gillett,[4] and others on the accumulation of impact data on a wide variety of metallic alloys. These investigations are valuable in the sense that they give data on what we may expect from such materials and might conceivably lay the foundation for specification values if and when such are considered necessary. The work of Langenberg[5] also gives us a more or less complete picture as to what we may expect from different steels at high temperatures.

In the field of cast iron, the Society's Committee A-3 on Cast Iron has an ambitious program mapped out and it is to be expected that in the near future we will have considerable data on the impact values for this material. It appears from the work of Wüst that in general the impact test for cast iron is considered satisfactory as a measure of brittleness.

As to throwing light on what impact values really mean, probably more work has been done in Germany than elsewhere. In that country, we are indebted to such workers as Moser,[6] Mailänder,[7] Fischer,[8] Fettweis,[9] and Korber.[10] It is now generally accepted that it is necessary to distinguish between specimens in which fracture is due to tension and those which have failed in shear. Only data obtained from specimens which have failed in the same way can be fairly compared. It can be seen from Mailander's work that in the case of shear failure (fibrous fracture) there is at a given notch width, an increase of impact strength with size of test specimen whereas for tension failure (granular fracture) the reverse holds. The variation in impact strength with size of test specimen in a series of geometrically similar specimens is not so great if the notches are equal in width as if they are strictly geometrically similar. Fischer's work is interesting in the light it throws on the large variety of test specimens used even in Germany. Korber's work shows that for comparison of different materials many factors must be considered. He shows curves of impact values from −200 to +500° C. and claims that such complete curves are necessary instead of single tests at normal temperature due to the fact that at one single test at normal temperature for a steel in one state may be on a flat portion of the curve and small variations may have little effect, but for the same material in a different state, the normal test may fall on that part of the curve with great slope.

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part II, p. 5 (1922).

[2] H. F. Moore, "Investigation of Fatigue of Metals," University of Illinois, *Bulletin No. 124*, p. 58.

[3] R. R. Moore, "Resistance of Metals to Repeated Static and Impact Stresses," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 547 (1924).

[4] H. W. Gillett, "Notes on Endurance Testing," *Proceedings*, Am. Soc. Testing Mats., Vol. 24, Part II, p. 476 (1924).

[5] "Behavior of Certain Steels Under Impact at Different Temperatures," The Iron and Steel Inst., *Carnegie Scholarship Memoirs*, p. 75 (1923).

[6] *Kruppsche Monatshefte*, Vol. 5, p. 42 (1924).

[7] *Stahl und Eisen*, December, 1926, p. 1752.

[8] *Kruppsche Monatshefte*, April, 1928, p. 53.

[9] "Werkstoff-Handbuch Stahl und Eisen," Verlag, Stahl und Eisen, 1927.

[10] *Mitteilungen*, K. W. Inst. Eisenforschungen, 1925, p. 43.

It appears, however, the impact test in its present arbitrary form has become more and more an adopted method of testing both in this country and in Europe, although this movement has gone much further in Europe. This raises the point as to whether or not some definite action should be taken by this Society at this time in including it in specifications.

So far as throwing light on the fundamentals of impact is concerned, we are very much in the same position as we were when the symposium was issued. We do know that when the time factor is shortened in the tension test a decided change in the material characteristics can be noted and when the time effect is shortened to an enormous degree as in the impact test, characteristics not shown by the tension test may be revealed. Since small changes in material may give large changes in impact values, it is to be expected that this test may show erratic results not shown by any other test.

It is to be noted that several lines of impact research are at present in progress in this country and this committee will see to it that the results when available are put before the Society in the form of papers. The recent publication by Davidenkov which is now being translated from the Russian will soon be available.

NON-METALLIC MATERIALS

In the field of non-metallic materials, a great deal of progress has been made. The application of the impact test to insulating materials, wood, and public roads will be separately considered.

Insulating Materials:[1]

Early in its consideration of the subject of mechanical tests for insulating materials, a subcommittee of the Society's Committee D-9 on Electrical Insulating Materials was of the opinion that impact tests would be of considerable value in view of the general characteristics of these materials. With practically no information available on the subject, and with no suitable machines, some time was spent in an effort to encourage equipment builders to produce a machine of the required sensitivity. Failing in this, the committee undertook the design and construction of its own machine.

A considerable amount of work along this line was done by a number of members, which stimulated interest in the test. Several machines were built and as a result of this activity a paper was presented in 1926[2] covering the development of suitable machines and presenting data on a number of phases of the impact test as applied to a variety of organic insulating materials.

The test was also found to be of great value as applied to porcelain and some data on the subject were presented by Louis Navias before the American Ceramic Society in 1927.[3]

The test was found to be so satisfactory and important that the the tentative methods of testing insulating materials for resistance to impact were issued in 1926, subsequently revised and amplified in 1928.[4] It includes methods for both Izod and Charpy type tests and covers porcelain, molded products and laminated sheets. The committee knows of fifteen companies that have built machines similar to those described in the papers and in the tentative standard. Presumably, the regular use of the test is now rather widespread.

It is a notable fact that the impact test is considered the most significant mechanical test of molded materials by those who have investigated it. This is particularly true among manufacturers of synthetic resins and molding compounds who considered it invaluable in work on the development and control of quality.

Experience has shown that at least with the same machine results are more consistent than is usually the case with other mechanical tests of these materials, and repeat tests from the same lot of samples will check with unusual accuracy. Tests have shown the results not to be critical in the usual materials to such factors as reasonable variations from the standard radius at the bottom of the notch—nor to slight errors in locating the notch relative to the jaws in the Izod machine (±0.015 in.). Yet the test is very critical in detection of apparently small variations in the material itself. This would indicate that in spite of the apparently arbitrary features of the test it is actually measuring an inherent and distinct property of the material. Unexpected variations between lots of samples supposedly the same are no longer charged to the peculiarities of the test as is so frequently the case in the metals field, but are taken as conclusive evidence of errors or uncontrolled variations in the manufacture of the material or samples. Improvements in apparatus and in process may be directly traced to this reliance on the impact test indications.

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[1] This section of the report has been prepared by Mr. W. W. Werring of the Bell Telephone Laboratories, Inc., New York City.

[2] W. W. Werring, "Impact Testing of Insulating Materials," *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part II, p. 634 (1926).

[3] Louis Navias, "Impact and Static Transverse Strength of Wet Process Electrical Porcelain," *Journal*, Am. Ceramic Soc., Vol. 10, No. 2, p. 90 (1927).

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1021 (1928); also 1929 Book of A.S.T.M. Tentative Standards, p. 625.

That the property measured by the notched bar test is directly related to impact failures in actual service is well established in this field. For example, tests of a wide variety of hard rubber compounds in extensive use will rank them in the order of excellence previously established by those familiar over a period of years with their manufacture and use. Incidentally, the unnotched test does not always parallel actual experience with these materials in this way. Also, an investigation of phenol plastic materials definitely established the fact that impact strength was dependent upon small variations of moisture content (of the order of 0.1 to 0.2 per cent), and it was predicted that breakage of indoor apparatus would be more serious in winter months. This effect has now been substantiated by service records over a period of 2 years on parts subject to impact.

In the paper "Impact Testing of Insulating Materials" it was pointed out that the test showed great possibilities as an indication of the progress of cure in the molding of phenolic resin materials. This has been further investigated and has not only proved of value in evaluating materials but by means of special machines the test is being applied to finished parts for the determination of the best molding conditions and optimum cure. As a result, impact strength requirements are being set on finished parts for inspection purposes.

While impact figures in terms of energy to break are not applicable to design problems, some work on the effect of size has been done. Navias reports that for round unnotched porcelain specimens, $\frac{3}{4}$ in. or over in diameter, the energy to break varies directly with the cross-sectional area. In the molded materials, Committee D-9 is considering expressing the value in terms of the product of the width by the square of the depth back of the notch for small variations in dimensions (±0.050 in.). T. S. Taylor reports that this relation gives fairly good agreement over a considerable range of size for rigid specimens, and the practice may be used to compare materials not available in the same size. However, with radical differences in size it is probably not sufficiently accurate for specification work.

The existence of fatigue effects in impact has long been a subject of interest in some sections of Committee D-9 and some work has been initiated on the subject. Although this has not as yet progressed very far, the existence of what might be termed a fatigue endurance limit seems clearly indicated in the case of at least some insulating materials.

In brief, it may be said that the whole subject of impact testing has been and still is of continued interest to the members of Committee D-9 and as a result of their development work the test is completely established in the field of insulating materials, and its importance and significance practically universally recognized.

Wood:[1]

In connection with wood, there are three problems which involv- impact testing: (1) determination of comparative properties of differe ent species; (2) determination of effect of various processes; and (3) acceptance tests.

As regards the first two problems, we can say that more progress has been made in adopting International Standards than in any other branch of impact testing. The method[2] described before the Society in 1922 affords a measure of stress at elastic limit and modulus of elasticity, as well as shock resistance. It is similar to that now adopted by the British Engineering Standards Association, the Canadian Forest Products Laboratory, the Indian Forest Service and that of the Union of South Africa. The New Zealand Forest Service is now considering its adoption. It may readily be seen that there is considerable unanimity of opinion in this field.

As regards the third problem of acceptance tests, a single drop test[3] with a pendulum is being recommended.

Studies at Bureau of Public Roads:[4]

For more than ten years, the U. S. Bureau of Public Roads has been making a study of the various phases of motor vehicle impact.

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[1] This section of the report has been abstracted from data supplied by Mr. L. J. Markwardt of the Forest Products Laboratory, Madison, Wis.

[2] T. R. C. Wilson, "Impact Tests of Wood," *Proceedings*, Am. Soc. Testing Mats., Vol. 22, Part II, p. 55 (1922).

[3] L. J. Markwardt, "New Toughness Machine is Aid in Wood Selection," *Wood Working Industries*, January, 1929.

[4] This section of the report was prepared by Mr. L. W. Teller of the U. S. Bureau of Public Roads, Washington, D. C.

This research has led to the examination of a number of methods for determining the magnitude of impact reactions. The experience which the Bureau has had in this field may prove of considerable value to others who may, from time to time, have similar problems.

It has been demonstrated by these tests that impact reactions may range in magnitude from less than the static wheel load to more than 70,000 lb. of instantaneous pressure.

A method for determining these impact pressures has been developed wherein the measured value is the vertical acceleration of the unsprung mass of the motor truck (wheels, axle, differential, etc.) when it is brought to rest by striking the pavement. The development of this method has led to an intensive study of accelerometers and the development of instruments suitable for this type of work.

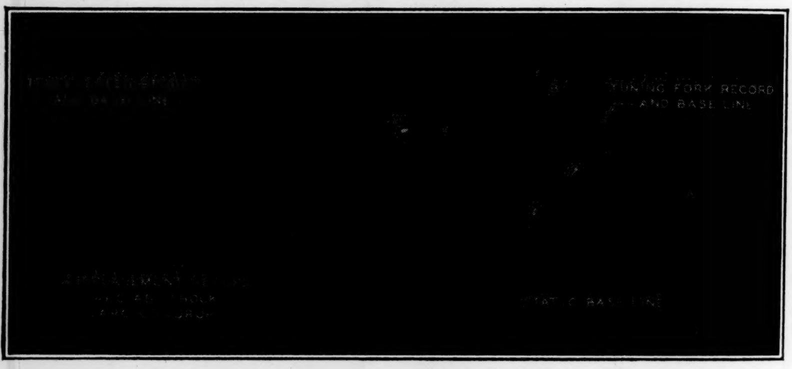

FIG. 1.—Typical Displacement-Time Record.

Accelerations have been encountered which range from less than one to more than eighty times that of gravity. The half cycle of the vibration period during which they occur varies from about 0.008 to about 0.08 second. The orders of displacement and velocity involved range, in general, downward from 1.0 in. per second and 10.0 ft. per second, respectively.

Displacement-Time Apparatus.—It has been possible to develop apparatus which gives a satisfactory record of the motion of a falling truck wheel in terms of time by means of a smoked paper traveling at about 40 in. per second passing under a fine stylus attached to the falling mass. A tuning fork makes a simultaneous trace on the record. A typical record is reproduced in the accompanying Fig. 1.

The analysis of such a record can be made by means of tabular first and second differences of displacement measurements taken at uniform intervals of time. From these tabular differences first and second derivatives are obtained by the use of established formulas. By the use of proper factors, these derivatives are converted into velocity and acceleration values. Every step in this analysis must be taken with precision. It is possible to reconstruct the original displacement-time relation to any suitable scale from the precise comparator readings used to obtain the tabular differences and to construct the corresponding velocity-time and acceleration-time relations from the analyzed data.

In its present form the apparatus is limited to laboratory set-ups. With careful work a probable error (in the determined values of acceleration) of between one and two per cent may be expected for moderate motor truck impact conditions.

The Kreuger Cell.—This device may be used to measure the total reaction between two bodies under either static or impact conditions. There are certain physical restrictions as to its use as well as a definite limit to the accuracy with which readings can be made.

The device consists essentially of a spherical surface of hardened steel in contact with a plane surface of the same material. Both surfaces are mounted within a pair of telescoping steel cylinders. When a force is applied normally to the point of contact, elastic deformation of the surfaces takes place and the area of contact increases with the pressure applied. The area of contact is recorded by a smoke film on the plane surface. The diameter of the record is measured with a Brinell microscope.

The apparatus is calibrated in a universal testing machine and our experience is that with careful operation the probable error is of the order of five per cent. The capacity of the cell and its sensitivity can be varied by changing the radius of the spherical surface.

Forces up to 30,000 lb., occurring in a period of time of less than 0.01 second, have been successfully measured.

The fact that this apparatus enables a direct measure of impact pressure, makes it of great value in checking (approximately) indirect methods for determining the same force.

Copper Cylinder Apparatus.—This device is similar to the Kreuger cell in appearance. However, the transmitted force permanently deforms a small specially annealed cylinder of pure copper, the amount of the deformation being a measure of the force applied. The same method is used by the Ordnance Department for measuring instantaneous gas pressures in the powder chambers of large guns. Very consistent results may be obtained but, for the measurement of impact, the method has the disadvantage that a relatively large displacement in the recording device occurs and this acts to reduce the magnitude of the impact reaction. In other words, the conditions of the impact are changed by this method of measurement.

Contact-Type of Accelerometer.—In this type of instrument, illustrated diagrammatically in Fig. 2, the acceleration to be measured acts upon a weight and creates a force which tends to deflect a steel beam. This tendency is resisted by the stiffness of the beam. This beam is really a calibrated cantilever spring whose stiffness is adjusted with a micrometer screw. Whether or not the impressed acceleration has been sufficient to deflect the beam is evidenced by the breaking (or completing) of an electrical circuit. Experiments are being conducted with mechanical autographic recording.

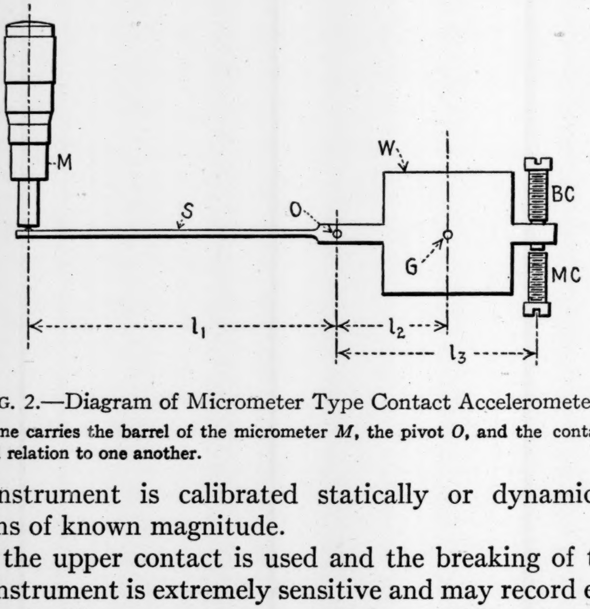

FIG. 2.—Diagram of Micrometer Type Contact Accelerometer.

A rigid frame carries the barrel of the micrometer *M*, the pivot *O*, and the contact screws *BC* and *MC* in fixed relation to one another.

The instrument is calibrated statically or dynamically with accelerations of known magnitude.

When the upper contact is used and the breaking of the circuit noted the instrument is extremely sensitive and may record extraneous accelerations leading to erroneous conclusions. When the completing of the circuit on the lower screw is used, the sensitivity of the instrument is decreased as the "gap" or motion of the beam is increased, although the extraneous or parasitic accelerations may be eliminated by this means. A single unit of this type has been used very successfully when the impact phenomenon could be repeated at will. Experiments are being made with a ten-element instrument of this type which is autographic and records accelerations within zones (whose limits are fixed by the stiffness to which the individual beams are adjusted). The first of these instruments was designed by B. Liebowitz.

Coil Spring Type of Accelerometer.—This is an instrument which was developed particularly for the Bureau's impact tests and with which a great deal of work has been done. It consists of a coil spring supporting a weight and supported in turn by a frame which is rigidly connected to the unsprung mass of the motor truck. An acceleration impressed on the weight creates a force which deflects the coil spring according to certain laws. The deflection of the spring is recorded by a stylus on sensitized paper, the length of the record being a measure of the acceleration.

The calibration factor for a given spring-weight combination bears a known relation to its natural period of vibration, obtained from the mass of the sensitive weight and the load-deflection rate of the spring. The period of the impressed acceleration modifies the calibration factor, and for the most accurate work this latter period should be known or closely estimated.

Impact Testing Machine.—This is a large portable machine, by means of which a motor truck wheel may be dropped upon a pavement in a controllable manner simulating closely impact reactions due to traffic. It consists of a truck wheel rigidly attached to the middle of a truck spring with mechanical means for raising this wheel and dropping it suddenly upon the pavement. Height of drop, truck spring pressure (spring load), type of wheel, tire or spring can be changed at will.

One of the important features of this machine is that a given impact phenomenon can be repeated as desired.

Reaction Wheel.— A large heavy wheel is arranged in bearings in a pit with the face of the rim level with the ground. A motor truck can be fixed with one rear wheel resting on this rim and this rear wheel driven by the truck engine as it would be on the road. Obstructions bolted on the rim of the reaction wheel thus pass repeatedly under the motor truck wheel producing impact. This enables impact phenomena closely simulating road impact to be studied in the laboratory.

Some of the important advantages are that shock and drop impacts produced with an actual motor truck may be studied by means of displacement time records. This has been done successfully under a wide range of speed, load and tire conditions.

Simple Harmonic Machine.—This is a laboratory machine designed and loaned by the Firestone Tire and Rubber Co. It consists of a platen which reciprocates vertically in simple harmonic motion by means of a "Scotch cross-head" connection to a massive flywheel revolving at a constant speed. The acceleration limit of this apparatus is 1400 ft. per sec. per sec. A 4-in. stroke is the maximum obtainable.

This device furnishes a very useful means for calibrating accelerometers dynamically.

Respectfully submitted on behalf of the Section on Impact Testing,

J. M. LESSELLS,
Chairman.

APPENDIX III

PROPOSED METHOD OF ANALYSIS FOR THE PARTICLE SIZE DISTRIBUTION OF SUB-SIEVE SIZE PARTICULATE SUBSTANCES, WITH COMMENTS[1]

1. *Scope.*—This method is intended for the determination of particle size of particulate substances in absolute units, in so far as the particle shape will permit.

(*a*) The material to be tested shall be homogeneous.

(*b*) Most of the materials dealt with such as powdered coal, cement, dust, pigments, and the like will be sufficiently fine that 50 per cent by weight passes the 74-micron (No. 200) sieve.

When it is desired to measure the size of materials finer than the 74-micron (No. 200) sieve which are less than 50 per cent of the weight of the sample, the material should be separated by sieving wet with a suitable fluid. That material which passes the sieve is recovered by evaporation of the fluid. The material which is retained on the sieve may be subjected to a standard sieve analysis and the additional material passing the 74-micron (No. 200) sieve shall be added to that which is to be tested.

When more than 50 per cent by weight of the sample passes the 74-micron (No. 200) sieve, elutriation may be applied directly and the residues in the coarse range subsequently subjected to sieve analysis.

(*c*) For pigments proceed directly.

(*d*) For wide ranges of particle size, separation is necessary to permit the examination and measurement with the microscope. Rough separation is permissible as exact-size measurement in microns follows. The following ranges of particle diameter are proposed for elutriation and sedimentation:

Range *A*....................................	48 to 24 microns
Range *B*....................................	24 to 12 "
Range *C*....................................	12 to 6 "
Range *D*....................................	6 to 0 "

Donald E. Cummings suggests that the number of ranges in Section 1 (*d*) be extended as follows: Range *D* to include particles of from 6 to 3 microns, and Range *E* to include particles of from 3 to 0 microns.

DEFINITIONS

2. (*a*) *Dispersion.*—In statistical work it is measured by the standard deviation. In microscopy it refers to the distribution of the individual particles. Both uses of the word seem too generally accepted to warrant a change in either.

(*b*) *Individual Particle.*—The term individual particle refers to those minute units of matter (of which the material is composed) whose size and shape depend only on the force of cohesion. Such particles cannot be subdivided without separating like molecules that are within the range of the cohesive attraction of one another[2].

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[1] Criticisms of this proposed method are solicited and should be directed to Mr. G. S. Haslam, chairman of the Section on Sub-Sieve Sizes of the Technical Committee on Size and Shape, of Committee E-1 on Methods of Testing, Research Division, The New Jersey Zinc Co., Palmerton, Pa.

[2] Henry Green, *Journal of Industrial Hygiene*, Vol. 7, p. 155 (1925).

(*c*) *Ultimate Working Unit.*—This may be an individual particle or it may be any group of individual particles that are so firmly held together by forces of adhesion that they remain intact as a group throughout the duration of their application.

(*d*) *Aggregate.*—Any group of two or more attached particles is an aggregate. There are three forms of aggregates: namely, ultimate working unit, flocculate and apparent flocculate.

(*e*) *Flocculate.*—Flocculation occurs only where particles have been incorporated in a liquid or plastic medium. A flocculate is a group of particles held together by a force, apparently arising from interfacial tension. This force of flocculation is relatively weak, consequently flocculates do not function as large individual particles, and cannot be classified under ultimate working units. Under slight continuously applied force flocculates are constantly breaking down and reforming.

Apparent flocculates as found in gas-floated or air-floated particles show a somewhat similar type of aggregation. Usually the force of attraction between the particles is relatively weak and the particles can readily be dispersed in suitable media. For practical purposes, the more inclusive term, aggregate, is preferable to flocculate for gas-floated or air-floated particles.

(*f*) *Average Diameter.*—An average diameter is the diameter of a hypothetical particle which, in some particular way, represents the total mass of particles.

(*g*) *Non-uniformity.*—A non-uniform particulate substance is one in which the constituent particles differ from one another in diameters.

Results will be expressed using one or more of the following average diameters:

AVERAGE DIAMETER	TO BE USED:	FORMULA
$\overline{d_1}$	As arithmetical mean........................	$d_1 = \frac{\Sigma nd}{\Sigma n}$
$\overline{d_3}$	To determine S when ρ is known................	$d_3 = \frac{\Sigma nd^3}{\Sigma nd^2}$
$\overline{d_4}$	To determine volume or weight distribution......	$d_4 = \frac{\Sigma nd^4}{\Sigma nd^3}$
$\overline{D}$	To determine N when ρ is known...............	$D = \sqrt[3]{\frac{\Sigma nd^3}{\Sigma n}}$
σ	To determine S when N is known..............	$\sigma = \sqrt{\frac{\Sigma nd^2}{\Sigma n}}$
M_g	As geometric mean or median..................	$\log M_g = \frac{\Sigma n \log d}{\Sigma n}$

SYMBOLS

S_m = specific surface in square meters per gram
S_v = specific surface in square meters per cubic centimeter
N_m = number of particles per gram
N_v = number of particles per cubic centimeter
Σ_n = number of particles in any given mass

ρ = Density of the material
θ = Arithmetic standard deviation
θ = Geometric standard deviation
P. E. = Probable error

E. J. Dunn, Jr., points out that in the ranges *A*, *B* and *C* specified in Section 1 (*d*) there are only two intervals of size to be measured by the microscope for each fraction. Separations that close in the higher ranges do not seem warranted. He suggests each of these fractions be subdivided into three class sizes. It would simplify the elutriation or sedimentation process and it is exceptionally easy to obtain a particle-size analysis on a sample containing only three or four intervals of size.

PROCEDURE

3. *Rough Separation Into Size Groups.*—Separation shall be made by liquid elutriation or by beaker sedimentation at room temperature. The volume of liquid in the elutriator or beaker should range between 20 and 100 ml. per gram of solid. With finer particles and with material of lesser density the greater volumes should be used. The technique involved in the elutriation or settling is necessarily influenced by the type of material being measured and the dispersing liquids. The size of the vessel and dispersion will be specified in terms of the uniformity obtained. The microscope measurement will be used as a check upon the effectiveness of the separation. For accurate results, at least 50 per cent by weight must fall within the boundaries of the suggested ranges specified for the elutriation. Of the material fallen without the boundaries not over 5 per cent by weight may fall outside of a range, which is one-half of the lower limit and twice the upper limit of the range under consideration.

Quite obviously, materials containing components of different densities will elutriate or settle in ranges of low uniformity. The present specifications can only be applied when the material conforms to the following requirements for homogeneity: If the materials can be readily identified under the microscope they may be measured individually and the results considered as exact, notwithstanding wide differences in density between two materials which may cause lack of uniformity. In other cases, such as cement or coal, where the presence respectively of gypsum and ash constituents may affect the test, these effects may be considered negligible for the normal type of products. The fluid used in the elutriator or settling work shall contain no dissolved solids which would influence the weight determination of a given portion, that is, the fluid shall be 100 per cent volatile. It shall not react chemically with the material being elutriated. Water, kerosine, alcohols, and the like may be used. It is suggested that the filtering of any elutriator portion should be through alundum to avoid contamination of the sample with paper or pulp fibers. As an alternative, the solid may be recovered from each stage of the elutriator by evaporation of a concentrated slurry, providing the temperatures used for the evaporation do not alter the specific product. The total weight of the portions recovered should check within 5 per cent the weight of material initially placed in the elutriator.

Donald E. Cummings states that he is convinced that in the procedure in Section 3 the limits specified are too wide and the method outlined too indefinite. This criticism applies particularly to dusts, which constitute industrial hazard. The original report which was submitted to the section contains a method considered suitable for this separation.

P. S. Roller takes exception to the requirements in Section 3 that "separation shall be made by liquid elutriation or by beaker sedimentation" on the basis of the work at the New Brunswick Station of the U. S. Bureau of Mines. With the air apparatus used at the New Brunswick Station, the fractions have not only been collected, but the sum of their weights checks closely the weight of the original sample. The results obtained with the air apparatus on a cement and chrome yellow pigment containing 79 per cent precipitated barium sulfate have been much more accurate than the requirements specified in Section 3. Indeed, on a weight basis, the overlap in each of the fractions has been but a few microns and not more than a few per cent. On the basis of these results Mr. Roller feels justified in calling the apparatus an air analyzer, rather than an elutriator which conveys the implication of qualitativeness.

The separations specified in Section 1 (*d*) for liquid elutriation and sedimentation are 48 to 24, 24 to 12, 12 to 6 and 6 to 0 microns. The separations made at the New Brunswick Station have been somewhat finer and were above 60 microns and 60 to 40, 40 to 20, 20 to 10, 10 to 5 and 5 to 0 microns. He believes that the important physical properties of a microscopic powder are below 20 microns, and is accordingly inclined to favor this system.

He states that while the dispersion obtained by Green,[1] using a glass rod and turpentine, has been excellent, he has entertained doubts regarding the validity of the procedure.

Rubbing the material into an extremely thin layer in turpentine either with the use of a glass rod or brush seems to Mr. Roller to involve the very serious danger of crushing the extremely minute particles. The possibility of error is still further enhanced because at the very high magnification used, the number of particles counted is relatively small.

Mr. Roller has made, for experimental purposes, microscopic tests on the various fractions which were separated by the air analyzer and has endeavored to incorporate a method whereby the larger particles are not lost at the expense of the finer grains which cling more tenaciously to the slide, and still not crush the microscopic particles. A counting of the fractions above 5 microns has been relatively easy because of the homogeneous nature of the fractions and interest has been concentrated on the 5 to 0-micron fraction in order to determine the distribution of particle size in this very important fraction. Mr. Roller presents the following method which has been found to give satisfactory checks and is extremely simple.

The slide is washed with soap and water and dried. A speck of the powder is placed upon the slide, breathed upon, and then tapped with the wooden handle of a spatula to roughly distribute the grains. A well grounded copper wire, which is so thin that it easily bends under pressure (about No. 30 gauge) is then used to spread out the powder into a thin transparent film, one layer in thickness. During this process the slide is occasionally moistened with the breath. For the finest fractions, as in the 5 to 0 or 3 to 0-micron range, a very good dispersion of the grains was obtained. In the same instances, an oil immersion lens was used on the dry preparation, and seemed quite suitable when the finest size measured was for particles grouped between 1 to 0 micron. As it has not been found necessary, no serious attempt has been made to immerse the finest fractions and mount them. It seems, by all means, that it would be preferable to use a dry mount with the cover glass merely cemented in place, even in measuring particles to a few tenths of a micron if the resolution is not too much impaired thereby. The relief, owing to the difference of index of refraction between the grains and the air medium, is excellent.

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[1] Henry Green, *Industrial and Engineering Chemistry*, Vol. 16, No. 7, p. 667 (1924).

PREPARATION OF THE MOUNT

NOTE.—Alternative methods are proposed, and other methods may be used when found suitable; dispersion and uniformity of distribution to be criteria of suitability.

A. Fine Materials, Pigments, Etc.:

4. (*a*) *Method of Dunn.*[1]—The type of mount that should be used for the particles depends on the physical properties of the particles. The most general mount advocated is a plain xylol and balsam mount referred to as a brush mount. For fine pigments, approximately four or five milligrams of powder shall be placed on a clean 3 by 2-in. microscopical glass slide. Two drops of balsam thinned with xylol shall be added and the mix brushed around the slide with a small, stiff-bristled brush until it is dry. Each bristle in the bundle of bristles acts like a single stirring rod so that the action is similar to two or three hundred stirring rods to disperse the particles. Once they are dispersed, the balsam keeps them dispersed. The balsam-xylol mix should not be too thin. When it is thin, it does not disperse the particles well. If the mix is too thick, the dried preparation will have too much depth for the normal depth of focus of most lenses. Depth causes some of the particles to be out of focus. Therefore, it is important to have a medium spreading consistency for the mounts. The density and dispersion of the particles in a mount shall be regulated for ease of counting.

Raymond P. Allen states that it appears improbable that in the Dunn method in Section 4 the particles once dispersed remain dispersed. There is also grave danger of segregation in this method.

(*b*) *Method of Green*[2].—About a milligram of the pigment shall be placed on the center of a microscope slide to which shall be added a drop of redistilled turpentine. The slide shall be held at the two ends between the thumb and first finger; a glass rod, with smooth, straight sides, so that it will come in close contact with the glass, shall then be used to disperse and rub out into an extremely thin layer the material in the turpentine. This may best be accomplished by a forward and backward motion of the rod in the direction of the length of the slide and extending over the central area only. The rubbing shall be stopped at a certain critical stage, when there still remains sufficient turpentine unevaporated to prevent the mount becoming "streaky," and yet not enough to float the particles which would allow them to flocculate. By a slightly upward flourish of the rod on the last stroke the mount can be made wedge shape, that is, dense in one part and thin in another, with all intermediate grades of density between. In this way it becomes possible to select a section for photographing that will show neither too many particles nor too few per given unit area. The mount shall be carefully examined and if there is any evidence of the larger particles being pushed to the sides, another mount shall be made or a different method used.

NOTE.—This method of dispersing the particles is to be used principally with the finest pigments, such as zinc oxide, lithopone, white lead, etc. In the case of these materials it will be found impossible to produce any grinding effect that will cause the individual grains to be broken up into smaller ones. This is on account of the fact that neither the glass slide nor the rod are optically flat, and consequently they are unable to come in close contact with each other except at very few points.

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[1] E. J. Dunn, Jr., ***Industrial and Engineering Chemistry***, Analytical Edition, Vol. 2, p. 15 (1930).

[2] Henry Green, ***Industrial and Engineering Chemistry***, Vol. 16, No. 7, p. 667 (1924).

After the material is properly dispersed, the remaining turpentine shall be removed completely. This shall be done by laying the slide on a hot plate, the temperature of which is sufficient to cause evaporation within 40 to 50 seconds. Care shall be taken that volatilization is complete. This may satisfactorily be ascertained by noticing if any odor of turpentine remains after heating. The particles will now be found to be cemented to the glass and should remain in this condition, if a reasonable amount of care is exercised in handling the slide. When sufficiently cooled a small drop of glycerin shall be placed on the center of the mount and then covered with a thin cover glass. The excess glycerin shall be carefully squeezed out at the sides of the cover glass and absorbed by filter paper. The mount shall be finished in the usual manner with a ring of Brunswick black.

If the above instructions have been properly carried out, and the mount now held to the light, the pigment, if its index of refraction is high, will just be perceptible as a faint cloud; if its refractive index is low, the pigment will be entirely invisible, except with a microscope.

Upon microscopic observation the following three essential conditions should be manifest:

(1) The particles will be in one plane.

(2) They will be free from Brownian motion.

(3) They will be dispersed, showing individual grains instead of aggregates and flocculates.

(*c*) *Method of Work.*—The method of Work that is described in Section 5 under Coarse Materials is also applicable to the preparation of the mount for fine materials, pigments, etc.

Donald E. Cummings states that he has obtained results as good if not better with 5-per-cent glycerin in alcohol as with the mixtures suggested in Sections 4 (*a*) and (*b*).

Raymond P. Allen believes that the rubbing method in Section 4 (*b*) is open to the danger of segregation. That is, in any range selected, say 12 to 6 microns, it is impossible to make a preparation in which there is uniform dispersion of all sizes. The large particles tend to collect at the edge. When this occurs, even great care will not insure the selection of a representative field. For a fairly uniform material such as zinc oxide, or some of the carbon blacks the method is suitable; for a material like whiting it is liable to introduce inaccuracy. He points out again the advantage of rubber or rubber cement in this application. The particles once dispersed, and dispersion is easy, will surely not segregate nor flocculate and a representative field can be selected at random. He also mentions the similar advantage of "Hydrax" which after dispersion of the pigment can be solidified without changing the degree of dispersion of the pigment. The chloronated naphthalenes may also be useful.

B. Coarse Materials, Ground Products, Etc.:

5. *Method of Work.*—The problem of securing uniform distribution becomes increasingly difficult with the larger elutriation fractions. Three small portions of elutriated material shall be withdrawn from the sample container. The contents of the sample container shall be thoroughly rolled or tumbled between

each removal. The portions shall be small but sufficiently large so that there is no tendency for one size of particle to roll off from the sampler, while another size is retained. The three portions shall be placed together on a 3 by 2-in. microscopic slide and mixed with a suitable volatile dispersing agent by lightly rolling them together with the end of a polished stirring rod or a rubber policeman. With a light circular motion, the path of the rod shall be extended outward spreading the particles into a larger area in such a manner that they appear to be evenly distributed. More dispersing agent shall be added as needed and the slide shall always be held in a horizontal position to avoid a drainage of dispersing agent with finely suspended particles. The dispersing agent shall be allowed to evaporate in the atmosphere or with the slow application of a uniform heat. Only slides which appear to be visibly uniform shall be used and the test for count shall be made at not less than five points representative of the entire area of the slide.

METHODS OF MEASUREMENT

6. *Direct Observation Using Filar Micrometer.*[1]—This type of measurement has been used with fair success and a reasonable degree of accuracy on the coarser fraction of particulate substances. It is an instrument that fits over the ocular of the microscope and permits direct measurement of the particle as viewed on the slide. This method, however, is not recommended for materials in the 6 to 0-micron class size.

7. *Projection Method.*[2]—The projection method which involves throwing the image of the particle on a screen has several distinct advantages. It further magnifies the image, permits focusing through the depth of the layer of pigment insuring a count of all the fines which may be present and has given excellent results with materials in the pigment range.

8. *Photomicrographic Method.*[3, 4]—The photomicrographic method, which involves taking a photomicrograph of the pigment particles and subsequently measuring them on a print or by projecting the negative on the screen, is also recommended. This method has the very decided advantage of making a permanent record of the sample and permits eye comparisons of two or more samples. In the use of this method it is extremely important that the mount shall be made in accordance with and shall conform to the requirements specified in Section 4 (*b*).

NOTE.—This procedure is to be used for elutriation fractions over 6 microns and it may also be used for the 6 to 0-micron range when found suitable.

In each of the three methods described in Sections 6, 7 and 8 the horizontal diameter shall be measured unless the particles are very uniform in shape and in that event a diameter which most nearly represents the average shall be selected. For irregularly shaped particles the horizontal diameter splitting the particle in half in one direction consistently maintained has been shown[5] to give fairly consistent and accurate results.

E. J. Dunn, Jr., states that it does not seem probable to expect particles to take an average position on a slide, while they are being dispersed. If the particles are irregular in shape it seems necessary to take an average measurement for the diameter. He believes that sufficient data have not been published to substantiate using a horizontal diameter.

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[1] Weigel, U. S. Bureau of Mines *Technical Paper 296* (1922).

[2] E. J. Dunn, Jr., *Industrial and Engineering Chemistry*, Analytical Edition, Vol. 2, p. 15 (1930).

[3] Henry Green, *Journal*, Franklin Inst., Vol. 192, p. 637 (1921).

[4] Sheppard and Lambert—not yet published.

[5] Martin, *Journal*, Am. Ceramics Soc., Vol. 23, p. 61 (1924).

SCALE LIMITS FOR MEASUREMENT

9. If more than 10 per cent by weight is coarser than 6 microns, the sample shall be elutriated prior to microscopic measurement. A graded scale for microscopic sizing is given as follows. If 20 per cent by weight of the material is less than 6 microns, the scale shall be treated as follows:

GENERAL CASE DIAMETER RANGE, MICRONS	SPECIAL CASE (LESS THAN 20 PER CENT UNDER 6 MICRONS)
72 to 60	
60 to 48	
48 to 36	
36 to 24	
24 to 18	
18 to 12	
12 to 9	
9 to 6	
	SAME SCALE AND
6.00 to 5.00	6 to 4.5
5.00 to 4.00	4.5 to 3
4.0 to 3.5	3 to 1.5
3.5 to 3.0	1.5 to 0
3.0 to 2.5	
2.5 to 2.0	
2.0 to 1.8	
1.8 to 1.6	
1.6 to 1.4	
1.4 to 1.2	
1.2 to 1.0	
1.0 to 0.9	
0.9 to 0.8	
0.8 to 0.7	
0.7 to 0.6	
0.6 to 0.5	
0.5 to 0.4	
0.4 to 0.3	
0.3 to 0.2	
0.2	

Two hundred and fifty particles shall be measured in each of three fields, taken at random.

The magnification shall be dependent on class size being measured, and shall be sufficient to permit the differentiation specified above.

Donald E. Cummings states he is thoroughly convinced that under scale limits for measurement, the magnification should be defined in terms of the particle size so that a fairly constant accuracy of measurement may be maintained. All measurements should be recorded in Hazens' logarithmic probability paper. A sufficient number of particles should be measured to get a straight line on this paper rather than to attempt to define a special number.

E. J. Dunn, Jr., suggests the following diameter ranges in microns to eliminate the decimals in the scale limits for measurements:

64 to 48 micron
48 to 32 "
32 to 24 "
24 to 16 "
16 to 12 "
12 to 8 "
8 to 6 "
6 to 4 "

This is a half ratio which also has a whole number for the average diameter of each interval of size, and does not carry decimals out into second place, such as the proposed range. He suggests the following for ranges *A*, *B* and *D* in Section 1 (*d*):

Range *A*	64 to 24
Range *B*	24 to 8
Range *D*	8 to 0

If four separations are to be made he suggests another separation below 8 or 6 microns, 20 intervals of size for fraction *D* are listed.

CALCULATIONS

10. If 90 per cent by weight fall in any one class size, the frequency curve shall be satisfactory, as follows:

The 6 to 0-micron class frequency or weight.

In elutriated products, weight distribution to be expressed as follows: Weight distribution shall be the basis of comparison for all elutriated samples. The weight distribution for each elutriated portion shall be calculated on the basis of spherical particles using the arithmetic mean of the microscopic class interval as the average diameter for all particles in that range. Each of the elutriated fractions shall total in weight distribution to the percentage retained in the elutriator and the composite curve shall be a summation of the distribution values in each range. The degree of overlapping is a measure of the efficiency of the elutriation and it should not be abnormal in amount.

REPORT OF COMMITTEE E-4

ON

METALLOGRAPHY

During the year, Committee E-4 has held three meetings, one at Atlantic City on June 27, 1929, one in Cleveland on September 11, 1929, and another in New York City on February 18, 1930, during the annual meeting of the American Institute of Mining and Metallurgical Engineers.

Subcommittee I on Selection and Preparation of Samples (E. H. Dix, Jr., chairman).—During the year the principal activity of this subcommittee was in connection with trying to obtain a satisfactory source of supply for polishing cloth. A number of samples were submitted to the committee for trial but none was found to be particularly acceptable. Several of the samples which were found to give satisfactory results could not be duplicated, but recently the committee believes that it has found a satisfactory cloth and a sample will be submitted at the next meeting of Committee E-4.

This subcommittee also has under consideration the revision of the Standard Methods of Metallographic Testing of Iron and Steel (E 3 – 24) and the Standard Methods of Metallographic Testing of Non-Ferrous Metals and Alloys (E 5 – 27), and the chairman reports that it is planned to go over these standard methods very carefully and submit to Committee E-4 recommendations for any changes which appear necessary. After this revision is completed it is hoped to recommend the submission of these methods to the American Standards Association for approval as American Standards.

Subcommittee II on Nomenclature and Definitions (Arthur Phillips, chairman).—The principal work of this subcommittee during the year has been the preparation of definitions of the terms "fiber" and "plasticity." A great deal of discussion arose on account of the fact that the general definitions of these terms, to make them suitable to all applications, had to be supplemented by very long notes or explanations to cover all possible variations of the general definition. At the February meeting of Committee E-4 a revised definition of "fiber in metals" was tentatively approved, but on account of the criticism that the kind of fiber due to dendritic segregation was not covered explicitly in the notes following the general definition, it was agreed to submit the definition back to Subcommittee II for further revision.

This revision has been made and the definition is as follows:

Fiber in Metals.—A condition of parallelism of important lines or details in the structure.

NOTE.—Fiber is nearly always associated with metal which has been wrought. In general, two distinct types of fiber are common. One type is due to segregated constituents, such as dendrites, slag, blowholes, carbides and oxides extended in the direction of working. Fibering of this nature is often detected by the character of the fracture but usually requires microscopic examination. The second type of fiber is produced by working. When a metal is worked below its recrystallization temperature, the grains or constituents themselves may be so changed in shape as to produce a condition of parallelism in the structure. Also under certain conditions of working, the crystal fragments tend to orient in certain definite directions with respect to the direction of working. Even in metals which have been annealed after cold working certain preferred orientations may be present. Fiber of this character is usually studied by X-ray methods, although it may be evident from the anisotropic properties of the metal.

With regard to the definition of "plasticity" submitted by the committee after some discussion, the following definition from which all the notes have been omitted was approved by the committee:

Plasticity.—In solid metals, that property by virtue of which they can be permanently deformed without rupture.

The committee believes that this simple definition covers all phases of the subject and needs no further explanation.

Further work of this committee was the consideration of the Glossary of Terms appearing in A.S.T.M. Standards and Tentative Standards, which was prepared by Committee E-8 on Nomenclature and Definitions and referred to Committee E-4 for criticism. The chairman of Subcommittee II and the secretary of Committee E-4 made some criticisms and suggested corrections which have been forwarded to the secretary of Committee E-8.

The subcommittee is also submitting a definition of the term "etching reagent," reading as follows, which has been approved by Committee E-4:

Etching Reagent.—A reactive substance used to reveal the structure of a metal or alloy through the development of differences in the appearance of different constituent parts or different grains.

This definition is intended to replace the present definition of "etching reagent," including the note appearing in the Standard Definitions of Terms Relating to Metallography (E 7 - 27). No change in substance is involved, merely a change in form to clarify the wording and it is recommended that the note which has been criticized be omitted.

Subcommittee III on Thermal Analysis (Howard Scott, chairman).—A revised Tentative Recommended Practice for Thermal Analysis of Steel which was presented at the June, 1929, meeting has been further revised and accepted by Committee E-4 for recommendation for publication as tentative, as appended hereto,[1] to replace the present Tentative Recommended Practice for Thermal Analysis of Steel (E 14 - 25 T).[2]

Subcommittee VI on X-ray Crystal Analysis (Zay Jeffries, chairman).—Subcommittee VI is not submitting a special report this year but it desires to call attention to a publication entitled, "X-ray Metallography in 1929" by Dr. George L. Clark, member of Subcommittee VI, Professor of Chemistry, University of Illinois, which was published in five parts in *Metals and Alloys* in the issues of July, August, September, October, and November, 1929. The committee also wishes to call attention to an abstract of X-ray work published by Deutscher Verband für die Materialprüfung der Technik entitled "Röntgentechnische Berichte." These abstracts are classified according to the following subjects:

1. Books and tabulated information;
2. Properties and physics of X-rays;
3. X-ray apparatus and technique;
4. Application of X-rays;
5. Miscellaneous articles pertaining to other fields.

Persons interested in the current literature pertaining to X-ray metallography will find the subject well covered in abstract in the two publications above mentioned.

At the June meeting of Committee E-4 the matter of "spheroidization" was considered and, at the suggestion of R. S. Dean that standard micrographs of tool steel showing various degrees of spheroidization and contamination by inclusions would be useful, the chairman of E-4 appointed Mr. Dean as chairman of this special committee to prepare standard micrographs as suggested, but to date no report has been received from this special committee.

Committee E-9 on Correlation of Research has made the recommendation that Committee E-4 consider doing some work relating to the crystalline structure of metals as compared with their strength and ductility. Some work has already been done along this line by Mr. C. H. Davis, a member of the committee, and his associates, and a paper is being offered at this annual meeting of the Society,[3] resulting in a good beginning in this field of research work. It is hoped that other members of the committee may start work along these lines as applied to metals other than copper and brass.

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[1] See p. 1259.—ED.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 25, Part I, p. 890 (1925); also 1929 Book of A.S.T.M. Tentative Standards, p. 803.

[3] See paper by C. H. Davis and E. L. Munson on "The Significance of Hardness Values for Some Copper-Zinn Alloys," *Proceedings*, Am. Soc. Testing Mats., Vol. 30, Part II, p. 522 (1930).

In its annual report for 1929, the committee submitted a set of standard micrographs for grain size of grain diameters ranging from 0.010 mm. to 0.200 mm. The committee recommends that this set of standard micrographs be now incorporated in the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (E 2 - 27).[1] The committee accordingly asks for the necessary nine-tenths vote for immediate adoption.

Various changes in the personnel of Committee E-4 have taken place during the year owing to the fact that several members have changed their places of occupation. The total number of members at the present time is 48.

The election of officers resulted in the unanimous selection of Mr. C. H. Davis as chairman, and Mr. O. E. Harder as secretary for the ensuing term of two years.

The recommendations appearing in this report have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. PROPOSED REVISION OF TENTATIVE STANDARD			
Recommended Practice for Thermal Analysis of Steel (E 14 - 25 T)	32	0	1
II. REVISION OF EXISTING STANDARD			
Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography (E 2 - 27)	32	0	1

This report has been submitted to letter ballot of the committee, which consists of 48 members; 33 members returned their ballots, of whom 32 have voted affirmatively, and none negatively.

Respectfully submitted on behalf of the committee,

G. F. COMSTOCK,
Secretary.

H. C. BOYNTON,
Chairman.

EDITORIAL NOTE

The proposed revision of the Tentative Recommended Practice for Thermal Analysis of Steel was accepted. The recommended practice in its revised form appears on page 1259.

The proposed immediate revision of the Standard Rules Governing the Preparation of Micrographs of Metals and Alloys, Including Recommended Practice for Photography as Applied to Metallography was approved at the annual meeting by a unanimous vote and was subsequently adopted by letter ballot of the Society on September 2, 1930. The standard rules in their revised form appear in the 1930 Book of A.S.T.M. Standards, Part I, page 898.

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[1] 1927 Book of A.S.T.M. Standards, Part I, p. 778.

REPORT OF COMMITTEE E-6

ON

PAPERS AND PUBLICATIONS

The Committee on Papers and Publications has had a number of interesting and rather important publication problems to consider during the year. The one of greatest importance, of course, is always the planning of the program of the annual meeting, and since it is of immediate interest it will be taken up first in this annual report to the Society of the committee's activities.

Program of 1930 Annual Meeting:

The program of this meeting is, the committee believes, one of the best that has ever been arranged. It is certainly one of the largest and most diversified, containing both among the committee reports and the technical papers subjects of interest in practically every field of activity in which the Society is engaged.

There are on the program reports from 49 committees of the Society, including 3 research committee reports on Yield Point of Structural Steel, Fatigue of Metals, and Effect of Temperature on the Properties of Metals. Four sectional committees for which the Society is sponsor under A.S.A. procedure are also reporting, on Classification of Coals, on Wrought Iron and Wrought Steel Pipe and Tubing, on Zinc Coating of Iron and Steel, and on Specifications for Plastering. The Special Committee on Copper Alloys in Ingot Form is also reporting, making a total of 54 reports on the program. In view of the fact that 1930 is the year of publication of the triennial Book of Standards, the standing committees have been engaged in bringing their standardization work up to date and their reports, therefore, are replete with recommendations for Society actions on standards and tentative standards. Despite this, it is quite interesting and significant to observe the extent of the investigative work that is reported by many of the Society's committees. There are a number of reports on the program to which papers have been appended, describing the results of researches under the committees' jurisdiction; and in recognition of the significance of these papers special mention has been made of them on the printed program of the meeting. Only one illustration will be cited, namely, the report of Committee C-9 on Concrete and Concrete Aggregates and that is so outstanding as to merit a word or two. The committee's report is one of the most comprehensive reports ever brought to the Society as a culmination of a year's work. While it represents considerable progress in the standardization work of the committee, the outstanding characteristic is the volume of information that is brought to the Society through researches planned by the committee and carried out by its members. The complete report will occupy, it is estimated, in the neighborhood of 200 pages of which unfortunately it has been possible to preprint only somewhat over half.

Considering briefly the technical papers on the program, the outstanding feature is undoubtedly the Symposium on Aircraft Materials. This symposium represents the first consideration that has been given by the Society to the problems surrounding the testing, specifying and application of materials of the aircraft industry—an industry in which, perhaps more than any other, exact knowledge of the properties of materials is necessary. The program of the symposium was arranged by an advisory committee of able and representative men under the chairmanship of Mr. Horace C. Knerr, a member of the Papers and Publications Committee. It will be seen from the program that practically every phase of the utilization of materials in aircraft construction, including both structure and engines of airplanes, has been covered; the papers are in the form of condensed digests and summaries and are intended primarily to comprise a convenient reference volume of authentic information which it is hoped will bring out equally valuable discussion.

A second Symposium on Rosin has been scheduled, as a continuation of a similar symposium held in 1926. This has been arranged under the immediate direction of Committee D-17 on Naval Stores.

In planning generally for the program of this meeting the Papers Committee has reviewed a number of fields in which the Society is actively engaged through committee work but for which technical papers dealing particularly with testing and properties of the material or product seem to be needed to round out the information on these subjects that is presented periodically to the members of the Society. Two fields selected for development this year are those of paints and rubber products. With the cooperation of the two committees on these subjects, very interesting programs have been arranged. The papers on paint testing comprise an entire session and cover measurement of hiding power of paints and pigments, determination of gloss, and the procedure for evaluating paint service. In the field of rubber testing it was decided to develop the subject of tests of rubber belting, and three authoritative papers on this subject appear on the program.

As usual there are a number of valuable contributions on the subjects of fatigue and corrosion of metals. Several papers deal with important non-ferrous metals; and in the Session on Steel are four important papers, three dealing with various types of alloy steels and the fourth on cold-drawn bridge wire—the latter a subject of particular significance at this time. The fields of cement and concrete are represented by a number of papers; and the ceramics field is represented by papers on freezing-and-thawing tests of clay brick and tests of roofing tiles. In the petroleum field there is an important contribution on the volatility of fuel as related to motor performance. A number of papers deal with methods and apparatus for testing including an interesting discussion of the measurement of thermal transmission of fabrics. In all there are 73 technical papers on the program.

The total of reports and papers on the program is 129, including the Annual Address of the President, and the Marburg Lecture—a figure considerably greater than in previous years. To accommodate this number of items within the period of four days that is customarily devoted to the annual meeting, it has been necessary to have one more session than in the past years, there being sixteen in all. It may be noted in passing that the program has been arranged differently than in recent years with the assigned period for recreation coming on Thursday afternoon instead of Friday afternoon, Friday being devoted exclusively to technical sessions.

As perhaps was to be anticipated with such a large program, it has not been possible to preprint everything for the meeting. A number of committee reports were submitted too late to be included in the first installment of preprints mailed on May 29. However, with one exception, all committee reports containing recommendations affecting standards were mailed in the second installment on June 14.

The volume of reports and papers expressed in number of printed pages is naturally greater than ever before. The following table gives complete information:

	REPORTS		PAPERS		TOTAL	
	NUMBER	PAGES	NUMBER	PAGES	NUMBER	PAGES
Preprinted	47	803	60	576	106	1379
Not Preprinted	7	270	13	230	21	500
Total	54	1073	73	806	127	1879

The comparative figures for the annual meeting last year illustrate the marked increase in volume of material for this meeting. There were on the program for last year 109 items (1367 pages), of which 100 items (1236 pages) were preprinted.

Selected A.S.T.M. Standards for Students:

Aside from the program of the meeting, the most important activity of the committee during the year has been the publication of a pamphlet of A.S.T.M. standards for the use of students in technical schools. More than a year ago the committee began a study of the possibilities of introducing a pamphlet into the technical schools, as a supplement to text books in courses in testing of materials. Through this study the committee was convinced that such a publication would be of distinct value and it was clear that many professors of materials would welcome opportunity to use such a pamphlet in their courses. The committee designated one of its members, Prof. A. N. Johnson, to head up a committee to select the contents of such a pamphlet, the other members being Messrs. T. R. Agg, H. J. Gilkey, H. C. Knerr and T. R. Lawson. This committee finally selected twenty-four specifications and methods of test representing a cross-section of the Society's standards that would seem to be of maximum usefulness to students in the study of materials of engineering. In addition, information about the Society, its purpose, membership and standardization procedure, was included, together with a discussion of "Factors and Principles Involved in the Enforcement of Specifications" based upon the classic presentation of this subject by the late Charles B. Dudley in his presidential address before the Society in 1907.

The pamphlet appeared in January of this year and met with immediate favorable response in the technical schools. The first printing of a thousand copies was sold in the first three months of the year, the price to students having been fixed at 50 cents. The second edition of two thousand copies has been printed, which will meet the needs of technical schools for their fall term, after which a new edition will be printed using the latest revisions of the standards embodied in the current 1930 publications. A number of suggestions have been received for other material to be included in the pamphlet and these will be considered by the Committee on Selection, which has been continued for this purpose.

The standards selected for this pamphlet have been those of interest primarily to engineering students and to students taking courses in materials testing. The committee is considering a suggestion that a companion pamphlet be prepared containing standards of more particular interest to students in chemistry, metallurgy and allied subjects.

At the request of the Executive Committee some consideration was given to the influence of the publication of the "Selected A.S.T.M.

Standards for Students" upon the student membership of the Society and the committee participated in the discussions that have resulted in the modified plan of student membership, on which the Executive Committee is reporting at this meeting.

Papers for Detroit Regional Meeting:

Another unusual event in the Society's publication year was the preprinting of the 12 papers that comprised the Symposium on Developments in Automotive Materials that formed the technical sessions of the Regional Meeting in Detroit. This meeting was under the auspices of the Detroit District Committee which appointed a Subcommittee on Program that planned the symposium and with the cooperation of the Papers and Publications Committee arranged for and assisted in the editing of the papers. As a matter of permanent record in the Proceedings of the Society the titles and authors of these 12 papers are given below:

1. Present-Day Methods in Production and Utilization of Automotive Cast Iron, by A. L. Boegehold;
2. Sheet Steel for Automobiles, by W. H. Graves;
3. Corrosion-Resisting and Heat-Resisting Steels for Automobiles, by Charles M. Johnson;
4. Advances in Die-Cast Metals for Automotive Use, by Charles Pack;
5. Developments in Light Metals and Alloys for Automotive Use, by Zay Jeffries;
6. Automobile Bearing Metals, by Clair Upthegrove;
7. The Significance of Various Tests for Motor Fuels, by R. E. Wilson;
8. The Significant Properties of Automotive Lubricants, by H. C. Mougey;
9. Evolution in Automobile Finishes, by M. J. Callahan;
10. Phenol Resinoids and the Automobile, by L. V. Redman;
11. Advances in Rubber for Automotive Use, by Walter C. Keys;
12. Recent Progress in Tests for Automotive Materials, by H. F. Moore.

Ten of the 12 were printed in advance of the meeting, the remaining two subsequently. The papers with discussion are being republished in the form of a bound pamphlet as a permanent record of the proceedings of this first regional meeting under the Society's auspices. The pamphlet will comprise about 175 pages. The expense of publication is being met jointly from Society funds and from funds raised by the Detroit District Committee.

Other Society Publications:

The usual regular publications of the Society were issued during the year, namely, the Proceedings of the Thirty-second Annual Meeting, the 1929 Supplement to the Book of Standards, the Index to A.S.T.M. Standards and Tentative Standards, and the Society

Year Book. The Book of A.S.T.M. Tentative Standards furnished to members on order was also published. The A.S.T.M. Bulletin appeared bi-monthly.

Several committees of the Society have continued their plan of arranging for annual publication in separate pamphlet form of their reports and the standards and tentative standards that they have prepared. These comprise: Report of Committee A-5 on Corrosion of Iron and Steel, 23 pages; Report of Committee D-2 on Petroleum Products and Lubricants, with related methods of test, 260 pages; Report of Committee D-9 on Electrical Insulating Materials, with related standards, 176 pages; and a reprint of a set of standard micrographs published as an insert plate with the annual Report of Committee E-4 on Metallography. Also a pamphlet entitled "Abstracts of Articles on Fatigue of Metals Under Repeated Stress Appearing in the Technical Press from July 1, 1928, to June 30, 1929," prepared by the Research Committee on Fatigue of Metals was published and distributed to all members in the fall of 1929. The demand for this valuable series of abstracts has justified the continuation of this work and the research committee is engaged in preparing abstracts of articles published in the year just ending. Following the annual meeting last year the papers comprising the Symposium on Physical Properties of Cast Iron were published in a single pamphlet with discussion, comprising 120 pages; and the papers comprising the Symposium on Mineral Aggregates were similarly published with discussion, comprising 162 pages.

Papers Presented at Committee Meetings:

The following papers have been reported to the Papers Committee as having been presented at committee meetings during the year: Committee D-13 Meetings, October 17–18, 1929, and March 13 and 14, 1930:

"A New Textile Abrasion Machine," by G. B. Haven;

"Strength Tests on Belting Fabrics," by B. L. Whittier;

"Progress of Cotton Fiber Studies," by R. W. Webb;

"The Development of Cotton Fibers," by Wanda K. Farr;

"The Quality of Cotton Produced and Consumed in the United States," by T. J. Cheatham;

"Influence of Different Factors on Variation in Length in Cotton Fibers," by R. Y. Winters;

"The Testing Laboratory and Its Relation to the Textile Mill," by R. H. Adams;

"Moisture Regain," by E. C. Gwaltney;

"Report of Investigation on E. C. Gwaltney's Regain Indicator," presented by G. B. Haven.

Some Current Publication Activities:

It is appropriate to mention several current publications which have recently engaged the attention of the committee or which will require its action within the next few months. Committee C-8 on Refractories has prepared a valuable "Manual for Interpretation of Refractory Test Data" which has been embodied in its report to the Society at this meeting. It is an important contribution towards placing methods of reporting data upon a sound statistical basis.

The List of Alloys prepared by Dr. William Campbell and first presented to the Society in 1922 with the annual report of Committee B-2 has recently been completely revised, brought up to date and supplemented by data on physical properties of certain of the alloys. The List is being reported to the Society with the annual report of Committee B-2 and will be available for distribution later in the year.

Committees A-10 on Iron-Chromium, Iron-Chromium-Nickel and Related Alloys and B-3 on Corrosion of Non-Ferrous Metals and Alloys are engaged in the compilation of data on the properties of ferrous and non-ferrous alloys with particular reference to their resistance to corrosion. This information is based upon detailed questionnaires circulated widely among the industries producing these materials, and will bring up to date similar information published by the Society in 1924. The data are being compiled and will be published with the reports of the two committees later in the year.

Respectfully submitted on behalf of the committee,

C. L. WARWICK,
Chairman.

REPORT OF COMMITTEE E-8

ON

NOMENCLATURE AND DEFINITIONS

Committee E-8 on Nomenclature and Definitions has now been in existence for ten years, having been organized in 1920. It is interesting to review the activities of the committee during these ten years and the progress it has made in the tasks originally assigned to it. One of its functions has been the review of definitions before their adoption as standard. With this in mind, all of the definitions submitted as tentative since its organization have been reviewed by its Editorial Committee and discussed with the standing committees responsible for the development of the definitions concerned. The definitions, after having been mutually agreed upon, have been formally approved by the committee. In this way, namely, through the approval of new tentative definitions and the approval of a number of standard definitions that have been revised and resubmitted as tentative in the intervening years, the committee up until the 1929 annual meeting had approved 270 definitions. With the number coming up for approval this year the total will be 360. This compares with 357, the number of standard and tentative definitions appearing in the standards of the Society when the committee prepared its first Index of Terms in 1920.

The committee will still have approximately 100 tentative definitions before it and there are approximately 150 standard definitions that have not yet received the review and approval of the committee. It will be seen that the committee has made considerable progress in the general review and approval of the wording of definitions. The committee has made no concerted effort toward reviewing definitions already adopted as standard and in securing modification of any of them. The committee, however, plans to undertake this work during the coming year and looks forward to having all of the definitions of the Society formally approved within the next few years.

When Committee E-8 was first organized it was contemplated that it would have a further function, in addition to the review and approval of individual definitions, of making a general survey of the fields covered by the Society in order that there might be a coordinated program of development and that definitions, as prepared by the individual standing committees, should be in accord with this general program. Up to the present time the committee has contributed in this to the extent of having broad definitions prepared wherever possible that would be generally applicable rather than restricted definitions limited in application to the work of the individual standing committees. The committee believes that it can function to even a greater extent in coordinating the development of definitions. The Glossary of Terms Appearing in A.S.T.M. Standards and Tentative Standards, which so far has been issued only in mimeographed form, has been and will be of considerable assistance in this, in affording a general review of the extent to which the several fields are covered and making evident where other definitions may be needed.

One matter that has received the attention of the committee during the past two years has been the form of note to be applied in the case of certain types of definitions. Two forms of notes are recognized, one applying to materials of basic character where there is one generally accepted use of the term but where the definition also applied to substitute materials; the second applying to definitions of products of manufacturing processes.

In the case of products of manufacturing processes a term might have a generally accepted meaning as applying to one specific product but also be used in connection with other products. Since a manufacturing process is involved it might well be that changes would come about that would cause the term to no longer have one generally accepted meaning. For this reason the note here applicable should read "in the present state of the art." The committee is accordingly adopting the following wordings for the two types of notes in question:

For the form of note applying to basic materials:

> When used without a qualifying adjective, the term ...... is generally understood to mean ......

For the form of note applying to products of manufacturing processes:

> In the present state of the art the term ......, when used without a qualifying adjective, should be understood to mean ......

In respect to the note applying to the products of manufacturing processes, the suggested form differs from that now in use in that it specifically distinguishes this form of note from that used for basic materials by using the expression "should be understood to mean," indicating a definite usage that should apply, whereas the first form of note uses the expression "is generally understood to mean" indicating a statement of fact of current usage.

The two forms of notes being adopted by the committee were published as information in the 1929 report of the committee and were referred to all the standing committees of the Society for comment before the committee took definite action to adopt them.

Glossary of Terms.—The Glossary of all terms appearing in the standards and tentative standards of the Society, was again issued during the year in mimeographed form and was brought to the attention of all members of Committee E-8 and the officers of standing committees. It has further received wide distribution as a result of an announcement appearing in the *A.S.T.M. Bulletin* that copies were available to all those interested.

A number of criticisms were received from the members of Committee E-8 and were transmitted to the committees concerned. In view of these some modifications are being made in the Glossary. The Glossary will again be issued in mimeographed form, containing all revisions resulting from actions taken at the annual meeting and the revised Glossary will again be brought specifically to the attention of the standing committees with the request that each standing committee comment on the definitions of any terms that would seem to be of interest in that committee, either suggesting modifications of the present definitions to make these definitions sufficiently broad to cover the applications to the work of that committee or, where this is not feasible, suggesting alternate definitions.

In preparing new definitions the standing committees should, of course, consult the Glossary to see if the terms which it is proposed to define are already included in the Glossary.

The definitions still before Committee E-8, either those being continued as tentative or those being recommended for adoption, are discussed below in greater detail.

DEFINITIONS OF TERMS APPROVED BY COMMITTEE E-8

In the report of the committee for 1929, a list was given of the 263 terms approved by the committee up to that time. At the 1929 annual meeting 7 additional terms were approved, as follows, making the total of definitions approved by Committee E-8, 270.

Asbestos Yarn
Cut
Metallic Asbestos Yarn
Plain Asbestos Yarn
Ply
Gage
Loop Knot

TENTATIVE DEFINITIONS BEFORE COMMITTEE E-8

Eighty-two definitions were submitted as tentative at the 1929 annual meeting, including 28 relating to magnetic testing, 53 relating to timber and 1 relating to wrought-iron specifications. The status of these definitions is given later in the report. Two definitions, namely, that for "leafing" (D 266) and for "absolute viscosity" (D 115) have been classed as not definitions. A number of tentative definitions were still before Committee E-8 for consideration, bringing the total to approximately 190. Grouped below according to subject matter, the present status of all of these terms is indicated.

Terms Relating to Wrought-Iron Specifications (A 81, A 84 and A 86).—Committee A-2 on Wrought Iron submitted at the 1929 annual meeting a tentative revision of the definition for "box pile" appearing in Specifications A 84 and A 86. The definition has been reviewed by Committee E-8 and some modifications suggested. The adoption of the definition, as modified, has been approved by Committee E-8. The definition in its modified form reads as follows:

> *Box Pile.*—In manufacturing wrought-iron bars, a pile, the outside of which is formed of flat bars and the interior of a number of small bars, all bars running the full length of the pile.

Committee E-8 has also suggested that the definition for "box pile" be incorporated with other definitions in the Standard Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 27).

During the year Committee A-2 has prepared a new definition for "wrought iron" which it is submitting for immediate adoption at the approaching annual meeting, asking for the necessary nine-tenths vote. The definition has been reviewed by Committee E-8 and approved with a minor editorial revision, making the definition read as follows:

> *Wrought Iron.*—A ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minutely and uniformly distributed quantity of slag.

The new definition for "wrought iron" is intended to be incorporated in the Standard Definitions A 81. In view of this, the Editorial Committee of Committee E-8 has reviewed all of the standard definitions of Committee A-2 and Committee E-8 has submitted modified wordings of these definitions to Committee A-2, suggesting that the definitions be revised in the light of the proposed modifications. These modifications are given below and, subject to their approval by Committee A-2, have been submitted to letter ballot in Committee E-8 for approval:

Puddling.—A process of making wrought iron by oxidizing and removing most of the silicon, carbon, manganese and phosphorus contained in pig iron in a reverberatory furnace.

Note.—"Puddling" formerly was applied only to the practice of employing refined pig iron, and "pig boiling" was the name applied when unrefined pig iron was used, but now this distinction is not generally made as the pig iron is seldom refined. Puddling as practiced today is really pig boiling.

Fagoting.—The making of a "fagot" or "box," the bottom and sides of which are formed of muck or scrap bars and the interior of miscellaneous iron scrap or a mixture of iron and steel scrap.

Common Iron.—Iron made from rerolled scrap iron or a mixture of iron and steel scrap, no attempt being made to separate the iron and steel scrap.

Refined Bar Iron or Refined Wrought-Iron Bars.—Iron bars rolled from a muck bar pile or from a box pile, of muck bars and wrought iron scrap bars free from steel, all bars running the full length of the pile.

Double Refined Iron.—Iron rolled from a slab pile or box pile of refined iron bars, all bars running the full length of the pile.

Slab Pile.—A pile built up wholly of flat bars of iron, all bars running the full length of the pile.

Terms Relating to Heat Treatment Operations (A 119).—The terms given below were prepared by a Joint Committee consisting of three representatives each of the American Society for Steel Treating, Society of Automotive Engineers and the A.S.T.M. They were submitted in 1927 for publication as tentative by the Society by Committee A-4 on Heat Treatment of Iron and Steel and subsequently revised in 1928. A few further modifications had since been suggested by the Joint Committee and Committee A-4 has approved these modifications and is this year recommending the definitions for adoption as standard as revised. Committee E-8 concurs in the recommendation of Committee A-4.

Heat Treatment
Quenching
Hardening
Annealing
Normalizing
Spheroidizing
Tempering
Malleabilizing
Graphitizing
Carburizing (Cementation)
Case Hardening
Case
Core
Cyaniding

Terms Relating to Magnetic Testing (A 127).—The following terms were submitted by Committee A-6 on Magnetic Properties at the 1929 annual meeting:

Magnetic Field (Field)
Magnetic Flux (Flux)
Magnetomotive Force
Magnetic Force (Magnetizing Force, Field Intensity)
Intrinsic Permeability
Permeance
Reluctivity
Reluctance
Remanence

Induction (Flux Density)
Normal Induction
Intrinsic Induction (Ferric Induction)
Saturation Induction
Permeability
Normal Permeability
Initial Permeability
Differential Permeability
Incremental Permeability
Reversible Permeability
Residual Induction
Retentivity
Coercive Force
Coercivity
Core Loss (Iron Loss)
Eddy Current Loss
Hysteresis Loss
Standard Core Loss
Aging (of magnetic materials)

These terms were reviewed by Committee E-8 prior to their submission as tentative and appear in satisfactory form. They are not, however, being recommended for advancement to standard this year and no action on their approval has been taken by Committee E-8.

Term Relating to Lime (*C 25*).—One term defined by Committee C-7 on Lime, namely, "available lime," is still under discussion with Committee C-7.

Terms Relating to Refractories (*C 71*).—Two terms defined by Committee C-8 on Refractories are continued as tentative as follows:

Spalling
Pyrometric Cone Equivalent (P.C.E.)

Comments in respect to these two definitions were forwarded to Committee C-8 and the definitions have been revised accordingly. The definitions are not being advanced to standard this year, however, and accordingly no action on their approval has been taken by Committee E-8.

Terms Relating to Gypsum.—Committee C-11 on Gypsum has before it as tentative the following terms:

Aggregate (C 11)
Consistency (C 11)
Gypsum Plaster Board (C 11, C 37)
Gypsum Wall Board (C 11, C 36)
Plasticity (C 11)

Definitions for "consistency" and "plasticity" have been under consideration in a Technical Committee on Consistency, Plasticity, Etc., of Committee E-1 on Methods of Testing. The definition for the term "aggregate" is still under consideration in a subcommittee of Committee E-8, as mentioned later in this report. The definitions for "gypsum plaster board" and "gypsum wall board" are still under discussion with Committee C-11.

The definition for "gypsum pottery plaster," approved by Committee E-8 as appearing in the Standard Definitions of Terms Relating to the Gypsum Industry (C 11 – 28) was revised in 1929 by Committee C-11. The revised definition, reading as follows, has been approved by Committee E-8 during the year:

Gypsum Pottery Plaster.—A material consisting essentially of calcined gypsum for use in making pottery molds.

A definition for "gypsum partition tile or block" appearing in the Standard Specifications for Gypsum Partition Tile or Block (C 52 - 27) was reviewed by Committee E-8 and revisions suggested to Committee C-11 which were found acceptable to that committee. The definition was accordingly revised to read as follows:

Gypsum Partition Tile or Block.—A gypsum building unit in form of tile or block for use in non-bearing construction in the interior of buildings and for the protection of columns, elevator shafts, etc., against fire.

Note 1.—The words "tile" and "block" are synonymous and are used so as to be in accord with certain freight association nomenclature.

Note 2.—Gypsum cored tile, 3 or 4 in. in thickness, may be split and used for furring purposes.

The definition is being formally approved by Committee E-8. It has also been incorporated by Committee C-11 in its Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 - 29 T).

Terms Relating to Paint (D 16).—The tentative definitions prepared by Committee D-1 on Preservative Coatings for Structural Materials are as follows:

Toughness
Elasticity
Screen (Sieve)

Committee D-1 is contemplating the preparation of additional definitions of terms relating to paint materials and a general review of its present standard definitions. The several definitions listed above will be given further consideration in this more general work on definitions now taking place.

Terms Relating to Petroleum Products.—The following terms appear in the methods of test and definitions prepared by Committee D-2 on Petroleum Products and Lubricants:

Alkali Neutralization Number (D 188)
Mineral Acid Neutralization Number (D 188)
Neutralization Number (D 188)
Crude Petroleum (D 288)
Topped Crude Petroleum (D 288)
Weathered Crude Petroleum (D 288)
Benzine (D 288)
Petroleum Naphtha (D 288)
Gasoline (D 288)
Petroleum Spirits (White Spirits) (D 288)
Kerosine (D 288)
Gas Oil (D 288)
Fuel Oil (D 288)
Tar, Pitch (D 288)
Petroleum Lubricating Grease (D 288)
Oil-Shale (D 288)
Crude Shale Oil (D 288)
End Point (D 288)
Engine Distillate (D 288)
Tops (D 288)
Specific Gravity (of Lubricating Oil) (D 287)
A.P.I. Gravity (D 287)

The definitions appearing in the Tentative Definitions of Terms Relating to Petroleum (D 288) are under consideration in the Subcommittee, of Committee E-8, on Definitions of Terms Relating to Petroleum Products. The three definitions appearing in the Tentative Method of Test for Neutralization Number of Petroleum Products and Lubricants (D 188) are still under discussion with Committee D-2. The two terms appearing in the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (D 287) will be taken under consideration in Committee E-8 during the coming year.

Terms Relating to Coal and Coke (*D 121*).—The tentative terms defined by Committee D-5 on Coal and Coke are as follows:

Coke
Beehive Coke
By-Product Coke
Coke Breeze
Dry Coke

These definitions with the exception of the term "coke" are being recommended for advancement to standard by Committee D-5. Committee E-8 had questioned certain features in respect to the definition for "coke" and also suggested a modification of the definition for "dry coke." It is understood that the latter modification will be acceptable to Committee D-5 and the definitions, with the exception of the term "coke," have been approved by Committee E-8 for adoption as standard. The term "coke" was referred back to Committee D-5 for further consideration.

Terms Relating to Timber (*D 9*).—At the last annual meeting Committee D-7 on Timber presented the following definitions as tentative:

Structural Timber
Annual Ring
Heartwood
Sapwood
Springwood
Summerwood
Pith
Defect
Blemish
Bark Pocket
Check
End Check
Heart Check
Surface Check
Through Check
Collapse
Honeycoming
Cross Break
Cross-Grained Wood
Curly-Grained Wood
Diagonal-Grained Wood
Dip-Grained Wood
Interlocked-Grained Wood
Spiral-Grained Wood
Wavy-Grained Wood
Decay
Advanced (or Typical) Decay
Incipient Decay
Firm Red Heart
Water-Soak (or Stain)
Knot
Pin Knot
Small Knot
Medium Knot
Large Knot
Encased Knot
Intergrown Knot
Loose Knot
Tight Knot
Pith Knot
Round Knot
Spike Knot
Decayed Knot
Sound Knot
Pitch Pocket
Small Pitch Pocket
Medium Pitch Pocket
Large Pitch Pocket
Pitch Streak
Shake
Through Shake
Sound Wood
Wane

Committee D-7 is recommending the adoption as standard of these definitions. They have been reviewed by Committee E-8 and, with certain editorial modifications which it is understood will be acceptable to Committee D-7, have been approved by Committee E-8.

Terms Relating to Insulating Materials (D 150, D 257).—The tentative terms before Committee D-9 on Electrical Insulating Materials are as follows:

Power Factor
Dielectric Constant
Loss Factor
Insulation Resistance
Volume Resistance
Surface Resistance
Volume Resistivity
Surface Resistivity

These definitions are generally satisfactory to Committee E-8. They are not, however, being recommended for advancement to standard this year and no action on their approval has been taken in Committee E-8.

Terms Relating to Rubber Products (D 297).—The following terms have been defined by Committee D-11 on Rubber Products:

Acetone Extract
Chloroform Extract
Alcoholic-Potash Extract
Free Sulfur
Total Sulfur
Ash
Sulfur in Ash
Total Compounding Ingredients

These terms are under consideration in Committee E-8.

Terms Relating to Textiles (D 123, D 258).—The following terms have been defined by Committee D-13 on Textile Materials:

Regain (Moisture Regain)
Rayon
Rayon Yarns
Spun Rayon
Nitro-Cellulose Rayon (Chardonnet)
Viscose Rayon
Cuprammonium Rayon
Cellulose-Acetate Rayon
Breaker Tire Fabric
Sheeting
Osnaburg
Airplane Fabric (Cotton)
Awning Cloth
Tent Duck
Webbing, Elastic
Dungaree
Burlap
Felt
Cockled
Broken Ends
Broken Picks
Hawser Twist
Cable Twist
Hard Twist
Twine
Rope
Laid Fabric
Holland
Book-Fold
Shoe-Fold

Of these definitions, the term "regain (moisture regain)" is being recommended for advancement to standard by Committee D-13. It has received the review of Committee E-8 and, with certain editorial changes which it is understood will be acceptable to Committee D-13, the definition has been approved by Committee E-8.

The remaining definitions are in agreement between Committee D-13 and Committee E-8.

Terms Relating to Methods of Testing.—Definitions for the following terms, prepared by Committee E-1 on Methods of Testing, appear in the Tentative Definitions of Terms Relating to Methods of Testing

(E 6 – 25 T), in the Tentative Methods of Compression Testing of Metallic Materials (E 9 – 27 T), and in the Tentative Methods of Tension Testing of Metallic Materials (E 8 – 27 T):

Stress
Strain
Stress-Strain Diagram
Tensile Strength
Compressive Strength
Modulus of Elasticity
Yield Point
Elastic Limit

With the exception of the definitions for "elastic limit" and "yield point" agreement has been reached between Committee E-8 and Committee E-1 in respect to the wording of these definitions and Committee E-1 is recommending their advancement to standard with the approval of Committee E-8. The terms "elastic limit" and "yield point" are receiving consideration in a Section of Committee E-1 on Elastic Strength of Materials.

SUBCOMMITTEE ORGANIZATION

Several of the definitions that have come under the purview of Committee E-8 are of interest to more than one standing committee and accordingly subcommittees were organized. None of these subcommittees, however, is prepared to present any recommendations in reference to the definitions at the present time. The Subcommittees on Definitions of the Terms Sieve and Screen; of the Terms Sand and Aggregate; and of the Term Concrete, were formerly under the chairmanship of Mr. L. R. Ferguson. On the resignation of Mr. Ferguson, Mr. F. E. Giesecke, as Committee C-9's representative, the committee chiefly concerned with these definitions, was appointed as chairman. A further change in chairmanship, however, developed during the year with a change in Committee C-9's representative, and Mr. Ernest Ashton is now serving as the chairman of these three subcommittees.

The terms under discussion in these three subcommittees include the following:

Screen (Sieve)
Sand
Aggregate
Gravel
Crushed Gravel
Screened Crushed Gravel
Concrete

A further Subcommittee on Brick is under the chairmanship of Mr. H. P. Tiemann. The committee has been inactive during the year and is not prepared to present a report at the present time. It is expected, however, that it will be in a position to make definite recommendations a year hence.

The Subcommittee on Definitions of Terms Relating to Petroleum Products is under the chairmanship of Mr. K. G. Mackenzie. The definitions under the jurisdiction of this committee are being discussed with the committees concerned.

Proposed Revisions of Definitions for Specific Gravity:

A Technical Committee on Methods for Density, of Committee E-1 on Methods of Testing, has been reviewing the Standard Definitions of Terms Relating to Specific Gravity (E 12 – 27) prepared by Committee E-8, and as a result suggested that the definitions be revised as follows:

1. In those cases where the temperature of the material and water are identical and are now stated as $x°$ C., the temperature should be stated as $x°/x°$ C.
2. In the definition for "specific gravity" include the requirement that water used as a reference basis be "gas-free" distilled water.
3. It was felt that the terms defined would be clarified if an example were given to accompany the definitions.

Committee E-8 has taken favorable action on the first and third recommendations but did not feel that a modification should be made in the definition of "specific gravity" by the reference to "gas-free" distilled water. This question had received considerable discussion when the definitions were developed and at that time the committee was quite agreed that the reference to "gas free" should be omitted.

The definitions recommended for advancement to standard have been submitted to letter ballot of the committee with the following results:

Items	Affirmative	Negative	Not Voting
I. ADVANCEMENT TO STANDARD OF TENTATIVE DEFINITIONS			
1. Definitions of Terms Relating to Methods of Testing (E 6 – 25 T) (Stress, Strain, Stress-Strain Diagram. Tensile Strength, Compressive Strength, Modulus of Elasticity)	29	0	4
2. Definitions of Terms Relating to Heat-Treatment Operations (A 119 – 28 T)	25	1	7
3. Definitions of Terms Relating to Coal and Coke (D 121 – 27 T) (Beehive Coke, By-Product Coke, Coke Breeze, Dry Coke)	22	0	11
4. Definitions of Terms Relating to Timber (D 9 – 29 T)	19	0	14
5. Definition of the Term Regain (Moisture Regain) (D 123 – 28 T)	22	0	11
6. Definitions of Terms Relating to Wrought-Iron Specifications (A 81 – 27; A 84 – 27; A 86 – 27) (Wrought Iron, Puddling, Fagoting, Common Iron, Refined Bar Iron or Refined Wrought-Iron Bars, Double-Refined Iron, Slab Pile, Box Pile)	21	0	12
7. Definitions of Terms Relating to Gypsum:			
Gypsum Pottery Plaster (Definitions C 11 – 28 and Specifications C 60 – 29)	19	0	14
Gypsum Partition Tile or Block (Definitions C 11 – 29 T and Specifications C 52 – 27)	19	0	14
II. APPROVAL OF FORM OF NOTE			
8. Approval of Form of Note to Definitions	30	0	3

The work of Committee E-8 is of such a nature that much of it can be handled by correspondence. Accordingly only one meeting was held during the year, on May 28, 1930. An election of officers was held and Cloyd M. Chapman was re-elected as chairman and G. W. Thompson as vice-chairman.

This report has been submitted to letter ballot of the committee, which consists of 47 members; 29 members returned their ballots, with the following results: advisory committee, 6 affirmative and none negative; standing committees, 23 affirmative and none negative.

Respectfully submitted on behalf of the committee,

CLOYD M. CHAPMAN,
Chairman.

R. E. HESS,
Ex-Officio Secretary.

REPORT OF COMMITTEE E-9
ON
CORRELATION OF RESEARCH

With this annual report to the Society, the Committee on Correlation of Research completes the sixth year of its activities. Its principal function has been to encourage and stimulate the work of the Society in promoting knowledge of materials through research, and in performing this function the committee has been brought into substantially an advisory capacity with the committees of the Society that carry on investigations in materials. Problems arise in research work in existing committees, often involving relations with other committees of the Society or with other societies; again, proposals for investigations in fields covered by our committee organization are made requiring consultation with committees. Sometimes, problems in unexplored fields are suggested. Such matters normally come to the attention of Committee E-9; new problems for study may be referred to an existing committee for development or may lead to the formation of a new committee. The committee seeks in this way to bring about studies of those properties of materials concerning which information is needed.

One of the functions of the committee is to review annually the progress of the Society's research activities. For this purpose the committee has from its inception recorded the development year by year in the various research projects under the Society's auspices, and in its previous annual reports has published a list of the projects in charge of each committee, with statements of scope. Since in preparing this list for publication there was of necessity no opportunity for reviewing the current research work of the committees, the list as published has never been completely up-to-date. It has accordingly been decided to prepare the review for this year *after* the annual meeting of the Society, so that it may include a record of research reported at this meeting. The review will also be along somewhat more critical lines than in the past; brief description of each project will be given, with references to committee reports and papers bearing upon the work. All projects that are not strictly research, or that are inactive, will be omitted. It has been recommended to the Committee on Papers and Publications that this review be issued in pamphlet form in the fall of each year and distributed to all members of the Society.

It will be of interest to mention briefly a few of the research activities of the Society.

Research in Metals:

In the field of metals, progress may be recorded in the work of the Research Committees on Yield Point of Structural Steel and on Fatigue of Metals. The latter committee is engaged in the preparation of the second number of "Abstracts of Articles on Fatigue of Metals Under Repeated Stress," covering the literature from July 1, 1929, to June 30, 1930, to appear next fall. A summary of present-day knowledge of fatigue of metals will appear in the committee's report this year.

Studies of the effect of temperature on the properties of metals have been continued under the auspices of the Joint A.S.M.E.—A.S.T.M. Research Committee on this subject, which has been reorganized during the year to provide a somewhat more effective group to handle the large and important problem assigned to it. With its preliminary studies practically completed, the committee is now preparing a research program for which adequate financial support from industry will be asked.

Studies of the effect of phosphorus and sulfur in steel by the Joint Committee in charge have been somewhat delayed by the inability of cooperating laboratories to proceed with testing as rapidly as desired. Valuable studies of cast-iron pipe are being carried on by a Sectional Committee on that subject. Studies of impact testing of cast iron have been started.

Studies on corrosion of metals by the various Society committees have proceeded actively during the year, with especial emphasis upon zinc-coated iron and steel sheets, wires and other products, various non-ferrous metals, and aluminum-base and zinc-base die castings. An extensive tabulation of the corrosion-resistant and other properties of the iron-chromium-nickel and related alloys has been completed.

A new research project was initiated this spring—a study of the causes of embrittlement of hot-dip galvanized structural steel. This study is being developed under the auspices of Committee A-5 on Corrosion of Iron and Steel with the cooperation of steel manufacturers, galvanizers and fabricators, the public utilities and the producers of zinc. The problem has an important practical bearing in the development of tests and specifications for zinc-coated structural steel, so largely used in power transmission lines.

Committee E-9 has requested the Research Committee on Fatigue of Metals to give some consideration to the possible relationship between caustic embrittlement and corrosion fatigue. It has also suggested to Committee E-4 on Metallography that some thought be given to the desirability of a thorough study in the Society on correlation between the mechanical and metallographic properties and attributes of metals. A proposal that the Society sponsor a periodic critical review of the literature on corrosion of iron and steel has been referred to Committee A-5 with favorable recommendations.

Committee E-9 is following with much interest the work of the Alloys of Iron Research Committee, functioning under the general direction of the Engineering Societies Research Board and the American Institute of Mining and Metallurgical Engineers. The purposes of this project are, briefly, to make available all reliable information in the great mass of literature in many languages; to publish the information; to correct and eliminate errors in existing data on iron and its alloys; and to increase the precision of data no longer adequate to the refinements of present-day industrial processes. The project is receiving adequate financial support by industry. The Society is represented in this work.

Research in Non-Metals:

Perhaps the outstanding research activity in the Society this year in the field of non-metals is that of Committee C-9 on Concrete and Concrete Aggregates. Studies extending over several years have come to a head this year, and the committee's report at this annual meeting contains a number of valuable reports and papers dealing with its several research projects. Included in the report are such subjects as elastic properties and volume changes of concrete; determination of constituents of concrete; abrasion of aggregates and its relation to concrete-making properties. Several technical papers have been inspired by the committee's research program, such as one on Haydite concrete, another on flow of concrete, and a third on volume changes. Many studies of methods of testing concrete are also reported.

Committee E-9 has given considerable attention to the subject of researches in mineral aggregates. Some of the outstanding problems in this field, especially as applied to the use of aggregates in roads and in all concrete construction, were brought into sharp relief by the Symposium at the annual meeting last year. Emphasis was laid upon the need for some group or agency to review and digest the information on mineral aggregates available at the present time. The committee is conferring on the subject with Committees C-9 on Concrete and Concrete Aggregates and D-4 on Road and Paving Materials.

Mention is made of progress in certain other researches in the non-metals field, such as fire tests of timber; accelerated testing of paints; abrasion, flexing and aging tests of rubber products; and tests and applications of rosin.

Presentation, Analysis and Interpretation of Data:

The committee has noted with interest the steps that have been taken this year in arranging for a coordinated study of the applications of modern statistical theory to the presentation, analysis and interpretation of engineering data. Committee E-1 on Methods of Testing has organized a Technical Committee to study the subject as applied to test data on materials, with especial emphasis upon applications of statistical theory in presenting data, in the planning of research programs, in establishing basic principles of sampling, and related problems.

Miscellaneous Administrative Matters:

The appointment in June, 1929, of H. C. Mougey, Assistant Technical Director and Chief Chemist, General Motors Corporation Research Laboratories, as a member of the committee for the term of five years is recorded. The term of office of H. F. Moore expires at the annual meeting this year; appointment of his successor will be made by the Executive Committee of the Society.

The balance of income from the A.S.T.M. Research Fund, as of April 10, 1930, was $578.12. (The principal of the Fund is at present $8387.85.) During the year, nominal financial assistance was extended to the Research Committee on Yield Point of Structural Steel and the Subcommittee, of Committee B-2, on Die-Cast Metals and Alloys to meet clerical and similar expenses for which other support was not available. The committee has offered to assist financially in the study of admixtures in concrete under the auspices of Committee C-9.

Respectfully submitted on behalf of the committee,

H. F. MOORE,
Chairman.

C. L. WARWICK,
Secretary.

REPORT OF COMMITTEE E-10

ON

STANDARDS

The Committee on Standards was formed by the Executive Committee as an administrative aid in the guidance and development of the Society's work in standardization of specifications and tests for materials. It was formally organized on October 9, 1929, with the following membership: Cloyd M. Chapman, T. G. Delbridge, J. H. Gibboney, E. F. Kenney and T. R. Lawson. Mr. Lawson was elected chairman; the Secretary-Treasurer serves *ex-officio* as secretary.

The functions of the committee have been defined broadly as follows:

1. To promote the standardization work of the Society;
2. To consider matters of general policy concerning standardization activities, including relationship with similar activities of other bodies;
3. To consider the desirability of expansion of standardization work into new fields;
4. To review annually the progress in the Society's standardization work; and
5. To pass upon proposed new tentative standards offered between annual meetings of the Society, in accordance with provisions of the Regulations Governing Standing Committees.

The committee will also act in an advisory capacity to the Executive Committee in standardization activities in general.

The committee begins its work at a significant and propitious period in the history of the Society. Appreciation of the industrial value of standards has steadily been growing, and today the industries of the country are supporting the development of standards to a greater degree than ever before. At the same time, the procedure evolved by the Society for formulation of standards is functioning smoothly and effectively and the work of the committees has been productive of new standards to a degree that could hardly have been predicted a decade ago. The number of standards and tentative standards issued in the several years of publication of the Book of A.S.T.M. Standards illustrates this growth; the number for 1930 is based upon the recommendations in the current reports of the standing committees:

YEAR	NUMBER OF STANDARDS AND TENTATIVE STANDARDS
1916	136
1918	177
1921	287
1924	405
1927	515
1930	579 (estimated)

Promotion and Expansion of Standardization Activities:

The promotion and further development of this work, and its expansion into new fields, is one of the major tasks of this committee. It will be the policy of the committee to seek the cooperation of the standing committees in surveying the fields assigned to them to determine where new standards may suitably be developed, and to secure the advice of the committees respecting suggestions for expansion of their work. The committee will determine from its own studies, aided by the many inter-society contacts now established, where work in entirely new fields would be desirable, and will make suitable recommendations to the Executive Committee. The cooperation of members through suggestions for new work will be especially helpful.

The importance of cooperation with other organizations engaged in standardization work is greater than ever before, because of the increasing extent to which technical societies and trade associations are becoming interested in standardization; and these cooperative relationships will engage the attention of the committee. The long-established policy of according representation of other societies and associations on committees of the Society has to an increasing degree led these other bodies to recognize the A.S.T.M. as the logical body to formulate standards for materials. Among a number of instances, several of the more important are cited: The American Society of Mechanical Engineers, in its Boiler Code work and in the engineering standardization work of other of its committees, looks to our Society for development of materials standards required for complete standardization of many mechanical engineering projects; the American Foundrymen's Association cooperates with the Society in the formulation of specifications for all foundry products; the American Petroleum Institute cooperates with the Society in the development of tests and, recently, specifications for petroleum products; various departments of the Federal Government incorporate A.S.T.M. methods of test in their purchase specifications; many industrial and trade associations look entirely to the Society for promulgation of standards applicable to their fields. It is the policy of Committee E-10 to firmly establish this position of preëminence of the Society in the formulation and promulgation of materials standards.

The Society's relationship with the national standardization movement, as expressed through the activities of the American Standards Association, is a most important one. The coordination of our work with that of other bodies through the A.S.A. is progressing in a number of fields, and developments during the year will be reported in the Annual Review of A.S.T.M. Standardization Activities, referred to later in this report.

The committee is giving particular thought to the relationship of the Society's standardization work with that of the Federal Specifications Board. The latter has developed specifications for materials and products, many of which are either based on or similar to specifications that have been promulgated by the Society. Conferences with the chairman of the Board have indicated that the development of F.S.B. specifications, which are intended primarily to control Government purchases, has reached the point where somewhat closer contacts may be maintained between the Board and the various committees of the Society; and the Society has offered its cooperation to the Federal Specifications Board whenever the Board is considering specifications falling within the field of the Society. At present a specific proposal for such cooperative contact between the specification committees of the Board and the specification-writing groups of the Society is being studied as applied to the development of metals specifications.

The relationship of A.S.T.M. standardization activities to those of the Division of Trade Standards of the U. S. Bureau of Standards, which is responsible for the promulgation by the Department of Commerce of "commercial standards," has also received the consideration of the committee. It has been agreed that whenever a suggestion is received by the Division to formulate standards on materials the Society will be advised for the purpose of ascertaining whether it has a committee dealing with the problem proposed or is prepared to form, if necessary, a new committee to undertake the proposed standardization. Through such an agreement, unnecessary duplication of effort is avoided, and the facilities of the Society for study of standardization problems are made more fully available to industry with the cooperation of the Department of Commerce.

Annual Review of A.S.T.M. Standardization Activities:

The committee considers that the assignment to it of an annual review of the progress of the Society's standardization work is of especial significance. This work is so many-sided and covers so many more or less unrelated fields that there seems to be a real need for a periodic summing up, in relatively brief compass, of the Society's accomplishments with particular emphasis upon standardization projects that are current in the standing committees. Although incidental to the primary purpose, which is to keep the members informed of this important side of their Society's work, the proposed annual review will serve the commendable purpose of giving greater prominence and publicity to A.S.T.M. standardization activities.

It has been decided that from the practical standpoint such a review may best be prepared after each annual meeting, thus giving opportunity for recording the formal actions of the Society on standardization work of the committees for the year and taking advantage of the fact that many committees plan their next year's work at meetings during the annual meeting, so that current activities can be more accurately presented in the review. These reviews will include the inter-society cooperative work in standardization, which is of increasing importance. Records of standardization activities in conjunction with the American Standards Association, including the work of sectional committees sponsored by the Society, will be an important part of the review.

The committee has recommended to the Committee on Papers and Publications that this review be published early in the fall in the form of a pamphlet to be distributed to all members of the Society. At the time of writing this report it is possible to make only an approximate estimate, in terms of new and revised standards, of the volume of the standardization work accomplished during the year and reported to the Society at this meeting. Thus the committee reports on the program include recommendations to the Society substantially as follows:

New tentative standards	21
Tentative revisions of existing standards	21
Revisions of tentative standards	25
Tentative standards recommended for advancement to standard	46
Revisions of existing standards recommended for adoption as standard	52
Changed from standard to tentative status	1
Standards and tentative standards withdrawn	6

There are at present 564 standards and tentative standards of the Society and if the above recommendations are approved this number will become 579.

Consideration of Proposed New Tentative Standards:

By amendment a year ago of the By-laws, the Society has established a new procedure whereby proposed new standards or proposed amendments of existing tentative standards may be presented between annual meetings of the Society and reviewed by Committee E-10 on Standards. The Society has charged the committee with the responsibility of determining in such cases, first, whether all requirements relating to the preparation and submission of standards have been compiled with and, second, whether the standing committee has reached a substantial consensus in its recommendations. The details of the procedure are clearly set forth in the By-laws of the Society and in the Regulations Governing Standing Committees, Section 15.[1]

Under this procedure the following proposed new standards and proposed revisions were submitted to the committee during the year:

Specifications for High-Early-Strength Portland Cement, submitted by Committee C-1 on Cement;

Specifications for Portland-Cement Concrete for Pavements, submitted by Committee D-4 on Road and Paving Materials;

Specifications for Ferro-Molybdenum, submitted by Committee A-9 on Ferro-Alloys;

Proposed revisions in Tentative Specifications for Calcium Chloride for Dust Prevention (D 98 – 22 T), submitted by Committee D-4 on Road and Paving Materials.

These proposed new specifications and revisions were considered at a meeting of the committee on February 18, 1930, with representatives of the standing committees concerned present and voting as members of Committee E-10 as provided in the Regulations. The committee's review of the Specifications for High-Early-Strength Portland Cement indicated that Committee C-1 had reached a substantial consensus in its recommendations and the specifications were accepted and promulgated as an A.S.T.M. tentative standard under the serial designation: C 74 – 30 T. Announcement of this action was made in the March BULLETIN and the specifications were published and distributed to the members in March.

In the case of the proposed Specifications for Portland-Cement Concrete for Pavements, the representative of Committee D-4 reported that a protest had been received from a member of that committee that insufficient time had been given for consideration of the letter ballot on the approval of these specifications. It was accordingly decided that the specifications be referred back to Committee D-4 for further consideration.

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[1] 1929 A.S.T.M. Year Book, pp. 257–259.

In the case of the Specifications for Ferro-Molybdenum it was felt that Committee A-9 had not reached a substantial consensus of opinion in favor of the specifications and they were referred back for further consideration.

In the case of the proposed revisions in the Tentative Specifications for Calcium Chloride for Dust Prevention (D 98 - 22 T), there were several negative votes in Committee D-4 and it was concluded also to refer these revisions back to the committee for further consideration.

In view of the serious responsibility that Committee E-10 has in acting in effect for the Society in determining whether a standing committee has reached a truly substantial consensus which justifies the acceptance of a proposed new standard as tentative, the committee plans to require that certain necessary information be given by the standing committees in offering new standards for promulgation through this procedure. Details of this procedure are being studied and will be announced later.

Miscellaneous Matters:

The committee has given consideration to a number of miscellaneous problems having to do principally with promotion of standardization activities and expansion into new fields. Brief mention is made of these items in the following paragraphs.

The committee has recommended to the standing committees of the Society that each committee establish an editorial subcommittee to eliminate inconsistencies in the form and substance of standards under their jurisdiction. Some committees of the Society have done effective editorial work which has proved especially helpful in the preparation of new specifications in those committees. The Headquarters staff in the course of its editing of standards for publication is able to accomplish much in making standards conform to requirements of form and style; but the most effective work of this kind may be accomplished in the standing committees themselves in the preparation of original drafts of standards. The practical importance of this work in maintaining and even raising the already high standard of the Society's publications justifies the fullest cooperation of the standing committees.

Consideration has also been given to the importance of adequate statements of scope of all A.S.T.M. specifications. The difficulty of defining the scope of certain types of specifications is recognized. It not infrequently happens that specifications for a given material written by a committee to cover its possibly limited field of application, and so defined in scope, is much more widely applicable than the title and scope would indicate. Where it can properly and safely be done there is decided advantage to the user of specifications in stating the fields of applicability covered by the material as specified. The committee plans to discuss this subject with the standing committees during the coming year.

The Executive Committee has charged Committee E-10 with the responsibility of selection of those A.S.T.M. standards and tentative standards which should be offered through appropriate procedure to the American Standards Association for approval as American Standard or American Tentative Standard. The committee has communicated with a number of standing committees and as a result several of the committees are prepared to recommend the submission of certain standards under their jurisdiction to the A.S.A for approval as American Standard under the "proprietary standards method." Under this plan, standards that have been developed by a representative committee and have met with general approval in industry may be submitted to the A.S.A. with a statement setting forth the history of the standard, the extent of use and the extent of approval in the committee responsible for its development. The committees recognize the importance of having A.S.T.M. standards approved as American Standard and it is desired as a matter of policy to expedite this work as much as possible. At present, 52 A.S.T.M. specifications and methods have been approved as American Standard and as American Tentative Standard.

As yet the committee has not been able to devote much consideration to the expansion of the Society's standardization activities into new fields. Several subjects were suggested during the year for development and were referred to the appropriate committees as follows:

Methods of analysis for phosphor tin, phosphor copper and silicon copper, and brazing solders, required in connection with specifications for these products prepared by Committee B-2; referred to Committee B-2 for development.

Methods of sampling and analysis of electrolytic cathodes; referred to the Coordinating Committee on Non-Ferrous Metals and Alloys for consideration.

Specifications and methods of test for leather; still under con-consideration in Committee E-10 with particular reference to specifications for leather belting, proposals for which have been made to the

American Standards Association and are being studied in an A.S.A. conference committee.

Respectfully submitted on behalf of the committee,

T. R. LAWSON,
Chairman.

C. L. WARWICK,
Secretary.

A.S.T.M.
TENTATIVE STANDARDS

SUBMITTED OR REVISED, 1930

The term Tentative Standard is applied to a proposed Standard which is printed for one or more years with a view of eliciting criticism, of which the committee concerned will take due cognizance before recommending final action toward its adoption as standard.

Members of the Society and others are invited to direct written criticism of any of these Tentative Standards to the officer of the appropriate committee, whose name and address appear in the footnote to the title of each Tentative Standard.

TENTATIVE SPECIFICATIONS
FOR
OPEN-HEARTH IRON PLATES OF FLANGE QUALITY[1]

A.S.T.M. Designation: A 129 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. These specifications cover three types of open-hearth iron plates of flange quality.

MANUFACTURE

Process. 2. The iron shall be made by the basic open-hearth process.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. The iron shall conform to the following requirements as to chemical composition:

	TYPE A	TYPE B	TYPE C
Phosphorus, maximum, per cent......	0.015	0.015	0.015
Sulfur, maximum, per cent...........	0.040	0.040	0.040
Total of the metalloids: carbon, manganese, phosphorus, sulfur and silicon, maximum, per cent...........	0.10	0.25	0.25
Copper, minimum, per cent..........	....	0.40	0.20
Molybdenum, minimum, per cent....	....	0.05	....

Ladle Analysis. 4. An analysis of each melt of open-hearth iron shall be made by the manufacturer to determine the percentages of each of the elements named for the respective types in Section 3. This analysis shall be made from a test ingot taken during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative and shall conform to the requirements specified in Section 3.

Check Analysis. 5. An analysis may be made by the purchaser from a broken tension test specimen representing each plate as rolled, in which a variation of plus 0.01 per cent in sulfur, minus 0.02 per cent in copper and plus 0.04 per cent in the total of the five metalloids will be permitted.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed by Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Steel Co., Conshohocken, Pa.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 6. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	44 000
Yield point, lb. per sq. in.	27 500
Elongation in 8 in, per cent	25

(*b*) The yield point shall be determined by the drop of the beam of the testing machine.

Modifications in Elongation. 7. (*a*) For material over $\frac{3}{4}$ in. in thickness, a deduction from the percentages of elongation specified in Section 6 (*a*) of 0.125 per cent shall be made for each increase of $\frac{1}{32}$ in. of the specified thickness above $\frac{3}{4}$ in.

(*b*) For material under $\frac{5}{16}$ in. in thickness, a deduction from the percentage of elongation in 8 in. specified in Section 6(*a*) of 1.25 per cent shall be made for each decrease of $\frac{1}{32}$ in. of the specified thickness below $\frac{5}{16}$ in.

Bend Tests. 8. The test specimen shall stand being bent cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness flat on itself; and for material over 1 in. in thickness, around a pin the diameter of which is equal to the thickness.

Test Specimens. 9. (*a*) Tension test specimens shall be taken parallel to the longitudinal axis and from the bottom of the plate as rolled. Bend test specimens shall be taken from the middle of the top and at right angles to the longitudinal axis of the plate as rolled. The longitudinal test specimen shall be taken in the direction of rolling and the transverse specimen at right angles to that direction.

(*b*) Tension and bend test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend test specimens may be machined with both edges parallel.

(*c*) Test specimens for plates over $1\frac{1}{2}$ in. in thickness may be machined to a thickness or diameter of at least $\frac{3}{4}$ in. for a length of at least 9 in.

(*d*) The machined sides of rectangular bend test specimens may have the corners rounded to a radius not over $\frac{1}{16}$ in.

Number of Tests. 10. (*a*) One tension and one bend test shall be made from each plate as rolled.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

(*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 6 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

PERMISSIBLE VARIATIONS IN WEIGHT AND THICKNESS

Permissible Variations.

11. The thickness of each plate shall not vary more than 0.01 in. under that ordered.

The overweight of each lot[1] in each shipment shall not exceed the amount given in Table I. One cubic inch of rolled open-hearth iron is assumed to weigh 0.2833 lb.

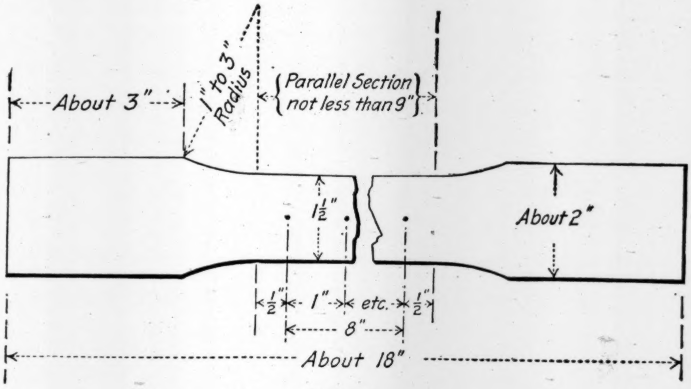

FIG. 1.

FINISH

Finish.

12. The finished material shall be free from injurious defects and shall have a workmanlike finish.

MARKING

Marking.

13. (*a*) The name or brand of the manufacturer, the manufacturer's test identification number, and tensile strength specified in Section 6 (*a*) shall be legibly stamped on each plate. The manufacturer's test identification number shall be legibly stamped on each test specimen.

(*b*) When specified on the order, plates shall be match-marked as defined in Paragraph (*c*) so that the test specimens representing them may be identified. When the plate rolled from a slab or ingot is cut into two or more smaller plates each shall be match-marked so that they may all be identified with the test specimens representing them.

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[1] The term "lot" applied to Table I means all of the plates of each group width and group thickness.

(*c*) Each match mark shall consist of two over-lapping circles each not less than 1½ in. in diameter, placed upon the shear lines, and made by separate impressions of a single-circle steel die.

(*d*) Match-marked coupons shall match with the sheets represented and only those which match properly shall be accepted.

INSPECTION AND REJECTION

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—PERMISSIBLE OVERWEIGHTS OF PLATES ORDERED TO THICKNESS.

Ordered Thickness, in.	Permissible Excess in Average Weights per Square Foot of Plates for Widths Given, Expressed in Percentages of Nominal Weights.									Ordered Thickness, in.
	Under 48 in.	48 to 60 in., excl.	60 to 72 in., excl.	72 to 84 in., excl.	84 to 96 in., excl.	96 to 108 in., excl.	108 to 120 in., excl.	120 to 132 in., excl.	132 in. or over	
Under ⅛	9	10	12	14	..	..	..	..	..	Under ⅛
⅛ to 3/16 excl.	8	9	10	12	..	..	..	..	..	⅛ to 3/16 excl.
3/16 " ¼ "	7	8	9	10	12	..	..	..	..	3/16 " ¼ "
¼ " 5/16 "	6	7	8	9	10	12	14	16	19	¼ " 5/16 "
5/16 " ⅜ "	5	6	7	8	9	10	12	14	17	5/16 " ⅜ "
⅜ " 7/16 "	4.5	5	6	7	8	9	10	12	15	⅜ " 7/16 "
7/16 " ½ "	4	4.5	5	6	7	8	9	10	13	7/16 " ½ "
½ " ⅝ "	3.5	4	4.5	5	6	7	8	9	11	½ " ⅝ "
⅝ " ¾ "	3	3.5	4	4.5	5	6	7	8	9	⅝ " ¾ "
¾ " 1 "	2.5	3	3.5	4	4.5	5	6	7	8	¾ " 1 "
1 or over	2.5	2.5	3	3.5	4	4.5	5	6	7	1 or over

NOTE.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on tests made in accordance with Section 5 shall be reported within five working days from the receipt of samples.

(*b*) Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 5, which represent rejected material, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS[1]

FOR

AUSTENITIC MANGANESE-STEEL CASTINGS

A.S.T.M. Designation: A 128 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. These specifications cover austenitic manganese-steel castings; this material is also often referred to as Hadfield's manganese steel.

MANUFACTURE

Process. 2. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, converter, or crucible.

Heat Treatment. 3. The castings shall receive a suitable heat treatment to render them tough and ductile. This heat treatment shall consist of uniformly heating the castings to a temperature of at least 1000° C. (1832° F.), holding them at the maximum temperature until they are uniformly heated throughout, and quenching them in water.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 4. The steel shall conform to the following requirements as to chemical composition:

Carbon	1.00 to 1.40 per cent
Manganese	10.00 to 14.00 per cent
Phosphorus	not over 0.10 per cent

Ladle Analysis. 5. An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified in Section 4. This analysis shall be made from drillings taken at least $\frac{1}{4}$ in. beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified in Section 4.

Check Analysis. 6. Analyses may be made by the purchaser on samples obtained from a casting. The samples for analyses shall be taken not less than $\frac{1}{4}$ in. below the surface in the case of rough castings. In the case of castings finished by grinding or machining, the samples for analysis may be taken at the finished surface, provided at least ¼ in. of metal has been removed from the casting at the point selected for sampling. The phosphorus content thus determined shall not exceed 0.11 per cent. The carbon content thus determined shall not be less than 0.90 per cent nor more than 1.50 per cent.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Steel Co., Conshohocken, Pa.

NOTE.—Contamination of the drillings by drill chips must be carefully guarded against. Flat drills of the best high-speed steels, or drills of some of the newer tool materials, will generally be satisfactory for drilling manganese steel. Manganese steel may be drilled best after it has been annealed for several hours at from 500 to 600° C.

PHYSICAL PROPERTIES AND TESTS

Bend Tests.

7. (*a*) Bend tests shall be required only when specified in the purchase order.

(*b*) When bend tests are specified, the test specimens shall stand being bent cold without breaking, around a pin 1 in. in diameter, to an angle of 150 deg. The bending may be by any method preferred by the manufacturer.

Alternative Tests to Destruction.

8. In the case of castings weighing not over 50 lb. and if satisfactory to the manufacturer and inspector, a test to destruction may be made as an alternative to bend tests when the latter are specified. For this test the castings shall be grouped in lots, each lot containing castings from the same melt and from the same heat treatment charge. From each such lot the inspector shall select one casting to represent the lot. The representative casting shall be tested to destruction by pressure or by blows. This test shall show the material to be tough and ductile, and suitable for the purpose intended. The cost of all such test castings shall be provided for in the purchase order.

Test Specimens.

9. (*a*) Bend test specimens, when specified, shall not be cast attached to the castings, but shall be poured in separate molds, from the same heat or melt of steel as the castings they represent. They shall be ½ by ¾ in. in cross-section and 12 in. in length, and shall be heat treated and tested without being machined or ground except when necessary to remove irregularities of surface, or to separate them from the runner or sprue through which they are poured.

(*b*) Bend test specimens, when specified, shall be heat treated with the castings they represent. When bend test specimens are heat treated with castings of comparatively heavy section, the test bars should be protected from oxidation by enclosing them in pipes or containers containing a small amount of carbonaceous material, and suitably sealed or luted to prevent the furnace gases from coming in contact with the test bars. To permit the expansion of the gases within these containers, they should not be completely sealed.

Number of Tests. 10. (*a*) When bend tests are specified, one such test shall be made from each melt or heat of steel in each heat treatment charge. When so specified by the purchaser, one bend test shall be made from the steel used for pouring each casting weighing 500 lb. or over.

(*b*) If any test specimen develops flaws and does not conform to the requirements specified, it shall be discarded, in which case another specimen from the same lot shall be substituted.

Retests. 11. If the results of the bend tests for any lot do not conform to the requirements specified, such lot may be reheat treated, but not more than twice. Retests shall be made as specified in Section 7 (*b*). In the case of reheat treatment and retest, when bend tests are specified in the order, two bend tests from a lot, or from each casting weighing 500 lb. or over, instead of one as specified in Section 10 (*a*), shall be required, both of which shall conform to the requirements specified in Section 7 (*b*).

WORKMANSHIP AND FINISH

Workmanship. 12. The castings shall conform to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser, with such tolerances as are customarily allowed, in the case of parts not finished to exact dimensions by grinding or machining.

Finish. 13. (*a*) The castings shall be free from injurious defects.

Welding. (*b*) Defects which do not impair the strength of the castings may be welded by an approved process. The defects shall be cleaned out to solid metal, before welding, and when so required by the inspector, shall be submitted to him in this condition for his approval. No welding shall be done except such as is approved by the inspector.

INSPECTION AND REJECTION

Inspection. 14. The inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the castings ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the castings are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment unless otherwise specified in the purchase order, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection. 15. (*a*) Unless otherwise specified, any rejection based on chemical analysis made in accordance with Section 6 shall be reported within five working days from the receipt of samples.

(*b*) Castings which show injurious defects subsequent to their acceptance at the manufacturer's works will be rejected and the manufacturer shall be notified.

Rehearing. 16. Samples tested in accordance with Section 6, which represent rejected castings, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

TENTATIVE SPECIFICATIONS
FOR
ZINC-COATED CHAIN-LINK FENCE FABRIC GALVANIZED BEFORE WEAVING[1]

A.S.T.M. Designation: A 118 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1930.

Scope. 1. These specifications cover zinc-coated chain-link fence fabric in which the individual pickets are helically wound and interwoven in the form of a continuous link fabric without knots or ties. The weight classification and all test procedure shall be in accordance with the Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A.S.T.M. Designation: A 110) of the American Society for Testing Materials.[2]

2. These specifications cover the usual sizes of wire and mesh as follows:

NOMINAL DIAMETER OF WIRE, IN.	SIZE, STEEL WIRE GAGE	SIZE OF MESH, IN.	HEIGHT OF FENCE FABRIC, IN.
0.192.......	6	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.148.......	9	2	36, 42, 48, 60, 72, 84, 96, 108, 120, 144
0.120.......	11	2	36, 42, 48, 60, 72, 84, ...
0.120.......	11	1¾	.. .. 96, 108, 120, 144

MANUFACTURE

Weave. 3. The wire shall be woven in the form of approximately uniform square mesh throughout, having parallel sides and horizontal and vertical diagonals of approximately uniform dimensions. The top and bottom of the fabric shall be knuckled or barbed as specified. The fencing shall be galvanized before weaving.

Zinc Coating. 4. The zinc used for the coating shall be any grade of zinc conforming to the requirements of the Standard Specifications for Slab

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. James Aston, Secretary of Committee A-5 on Corrosion of Iron and Steel, Department of Mining and Metallurgy, Carnegie Institute of Technology, Pittsburgh, Pa.

[2] 1930 Book of A.S.T.M. Standards, Part I, p. 409.

Zinc (Spelter) (A.S.T.M. Designation: B 6) of the American Society for Testing Materials.[1]

Base Metal. 5. The base metal of the fabric shall be of a good commercial quality of steel or iron wire. If copper is desired, the copper content shall not be less than 0.2 per cent.

WEIGHT AND UNIFORMITY OF COATING

Tests of Coating. 6. The weight and uniformity of the coating shall be defined and tested in accordance with the requirements of the Standard Methods of Testing Zinc-Coated (Galvanized) Iron and Steel Wire and Wire Products (A.S.T.M. Designation: A 110) of the American Society for Testing Materials.[2]

7. The weight and uniformity of the coating for the various gages of wire composing the fencing shall be as specified by the purchaser and in accordance with the weights and dips designated in Table I.

TABLE 1.—ZINC-COATED CHAIN-LINK FENCE FABRIC GALVANIZED BEFORE WEAVING.

NOMINAL DIAMETER OF WIRE, IN.	SIZE, STEEL WIRE GAGE	CLASS DESIGNATION WT. 5 DIP 3
0.192	6	✓
0.148	9	✓
0.120	11	✓

NOTE.—Sizes in which any given weight of coating may be regularly obtained in the open market are indicated by a ✓ opposite the gage in the above table.

SIZE AND PERMISSIBLE VARIATIONS

Size. 8. (*a*) The size of the finished wire shall be expressed as the diameter of the wire in decimal fractions of an inch.

Permissible Variations. (*b*) The permissible variations from the nominal diameter shall be plus or minus 0.004 in.

PACKING AND MARKING

Packing and Marking. 9. The continuous lengths of fence fabric shall be 25, 50, or 100 ft., or as specified. Each length of fabric shall be tightly rolled and firmly tied. For ease of handling, consideration should be given to the weight of the roll, depending upon the length of fabric. Each roll shall carry a tag showing the class of coating, the nominal weight of coating, the gage of the wire, the length of fencing in the roll, and the manufacturer's name or mark.

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 582.

[2] *Ibid.*, p. 409.

INSPECTION, SAMPLING AND REJECTION

Inspection. 10. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy himself that the material is being furnished in accordance with these specifications. All tests and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Billing. 11. All rolls of fencing accepted by the purchaser shall be billed to him on the basis of the original weight or footage of the rolls before sampling.

Sampling and Rejection. 12. For purpose of tests, one roll for each 10 per cent of the rolls of fabric in shipments of less than fifty rolls shall be taken as a sample. One roll representing each 5 per cent of the rolls in shipments of over fifty rolls shall be taken as a sample. In no case shall there be less than three samples taken. The specimens for testing shall consist of one square foot of woven fencing selected at any point in the width of the fence fabric, exclusive of the twisted or knuckled portions, and taken from the end of the roll. A specimen from each sample shall be subjected to the test for the weight of coating in accordance with Sections 6 and 7; and a specimen from each sample shall be subjected to the test for the uniformity of coating in accordance with Sections 6 and 7.

By means of the following formulas, the wire surface area in square feet contained in one square foot of the fabric can be calculated, to facilitate the computation of the surface area of the specimens:

Square feet of wire surface of Size 6 (Steel Wire Gage) wire = 0.516 W
" " " " " " " 9 (" " ") " = 0.674 W
" " " " " " " 11 (" " ") " = 0.830 W

where W = the weight in pounds of wire in one square foot of fabric after being stripped of galvanizing.

If any specimen tested fails to meet the requirements of these specifications, two additional specimens shall be cut from the remainder of the sample and tested, both of which must meet with the requirements in every respect or the lot represented by the sample may be rejected.

TENTATIVE SPECIFICATIONS
FOR
CHILLED-TREAD CAST-IRON WHEELS[1]

A.S.T.M. Designation: A 46 – 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

MANUFACTURE

Material. 1. Wheels shall be made of a mixture of such composition that, with good foundry practice and proper annealing, they will have the required chill in the tread, and otherwise meet the requirements of these specifications.

Fracture. 2. The fracture shall show a soft, clean gray iron free from defects such as holes more than $\frac{1}{4}$ in. in diameter containing slag or dirt, or clusters of holes honeycombing the hub, or white iron in the plate or hub.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 3. The wheels shall conform to the following requirements as to chemical composition:

	MINIMUM	MAXIMUM
Total carbon, per cent	3.00	....
Combined carbon, per cent	....	0.90
Manganese, per cent	0.50	....
Phosphorus, per cent	....	0.50
Sulfur,[a] per cent	....	0.14

[a] *Sulfur Content.*—The essential condition of chemical composition of chilled-tread wheels is a balance between sulfur, carbon and manganese, and variation in these constituents must not disturb this relation. If on check analysis, the sulfur is found to be not more than 0.02 per cent greater than that specified, it shall not be considered sufficient cause for the rejection of the wheels, provided that the wheels conform to all physical and inspection requirements and provided that the manganese content is at least three and one-half times the sulfur content. Such failure to conform to the specifications should be called to the attention of the manufacturer and subsequent shipments or lots shall conform to the specifications.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. W. H. Rother, Secretary of Committee A-3 on Cast Iron, 1543 Fillmore Ave., Buffalo, N. Y.

These specifications, when adopted as standard, will supersede the present Standard Specifications for Chilled Cast-Iron Wheels (A.S.T.M. Designation: A 46 – 24), 1930 Book of A.S.T.M. Standards, Part I, p. 485.

Chemical Analyses.

4. Analyses shall be made by the manufacturer from test blocks poured during the day's melt from each cupola from which wheels purchased to these specifications are poured. The percentages of manganese, phosphorus and sulfur shall be determined. The determination of carbon shall also be furnished merely for information. A copy of the analysis shall be furnished the purchaser or his representative on request.

Check Analysis.

5. An analysis may be made by the purchaser from one of the test wheels representing each 100 wheels. The sample for analysis shall be taken from drillings obtained by drilling a hole into the back of the plate of the wheel midway between the flange and the hub. The chemical composition thus determined shall conform to the requirements for manganese, phosphorus and sulfur specified in Section 3.

Chemical Analysis Procedure.

6. Chemical analyses shall be determined in accordance with the Standard Methods of Sampling and Chemical Analysis of Pig and Cast Iron (A.S.T.M. Designation: A 64) of the American Society for Testing Materials.[1]

Shipment of Wheels.

7. The purchaser shall not require the manufacturer to hold all lots of wheels until check analysis can be obtained unless it has been found that the manufacturer's product has not been conforming to these specifications.

PHYSICAL PROPERTIES AND TESTS

Thermal Test.

8. (*a*) In making the thermal test, the wheel shall be laid with the flange downward in the sand with the channelway molded in green sand around the wheel, 4 in. deep and of a width as shown in the following table. The tread of the wheel shall form one side of the channelway, the clean flange forming as much of the bottom as its width will cover. This channelway shall be filled with molten cast iron, which shall be hot enough when poured so that the cast ring, when cold, will be solid and free from wrinkles. The time when pouring ceases shall be noted, and after the time specified in the following table has elapsed, the wheel shall be examined. If a crack develops in the wheel within the time limit specified in the table all wheels bearing that same tape size shall be rejected.

WEIGHT OF WHEEL, LB.	COOLING TIME, MINUTES	WIDTH OF CHANNELWAY, IN.
650	3	2
700	5	2
750	5	3
850	7	3

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 506.

(*b*) The use of a permanent mold for making the thermal test in place of the sand mold described in Paragraph (*a*) is permissible. The permanent mold shall consist of an iron ring and bottom board of such dimensions that the wheel to be tested can be immediately placed in the mold and centered to the required channelway.

(*c*) In order to prevent spitting while pouring, the tread and flange may be covered with a coat of chiller paste. Wheels selected for test which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances shall the thermal test be applied to a wheel that in any part feels warm to the hand.

Drop Test. 9. (*a*) The test wheel shall conform to the drop test requirements given in the following table without breaking in two or more pieces. If the test wheel fails all wheels bearing the same tape size shall be rejected:

Weight of Wheel,		Weight of Tup,		Height of Drop,		Number of Blows
lb.	kg.	lb.	kg.	ft.	m	
650	295	250	113	9	2.75	12
700	317	250	113	10½	3.20	12
750	340	250	113	12	3.65	12
850	385	250	113	15	4.57	12

(*b*) If the test wheels crack in the plate with three blows or less, they shall be considered as having failed.

(*c*) *Apparatus.*—The anvil of the drop testing machine shall weigh not less than 1700 lb. (770 kg.) and shall be supported on a foundation of rubble masonry or concrete at least 2 ft. (61 cm.) in depth. The striking face of the tup shall be flat and 9 in. (229 cm.) in diameter. The face of each of the three bosses supporting the wheel under test shall be flat and 5 in. (12.7 cm.) in width. The test wheel shall be so placed on the three supports, with the flange down, that the tup will strike centrally on the hub.

Chill Test. 10. (*a*) After having been subjected to the thermal and drop tests, the test wheels shall be broken so that the chill may be examined at at least four different portions of the wheel. The depth of pure white iron shall conform to the following requirements and the depth of the chill shall not vary more than ¼ in. (6.35 mm.) in the middle of the tread on the different portions measured:

Weight of Wheel,		Maximum Depth,		Minimum Depth,	
lb.	kg.	in.	mm.	in.	mm.
650	295	1	25.5	$\frac{3}{8}$	9.5
700	317	$1\frac{1}{16}$	27	$\frac{7}{16}$	11.1
750	340	$1\frac{1}{8}$	28.6	$\frac{1}{2}$	12.7
850	385	$1\frac{1}{8}$	28.6	$\frac{1}{2}$	12.7

(*b*) If the test wheel does not conform to the requirements specified, all wheels of the tape size represented by the test wheel shall be rejected.

NOTE.—The physical properties and tests specified cover only 33-in. wheels of the weights listed. Requirements for wheels of other sizes are to be supplied by the committee.

Number of Tests. 11. (*a*) *Sampling.*—When ready for inspection, the wheels shall be arranged in groups, all wheels of the same weight being grouped together, and for each 102 wheels which pass inspection and are ready for shipment, two representative wheels shall be taken, one of which shall be subjected to the thermal test and the other shall be used for the drop test.

(*b*) When ordered in lots of 100 or more of each weight, the manufacturer shall arrange to cast them in sufficient quantity so that at least one test wheel may be taken from the wheels cast each day.

DIMENSIONS, WEIGHT AND DESIGN OF WHEELS

Patterns. 12. Patterns and chillers shall be such that they will produce wheels in accordance with the dimensions shown on drawings furnished by the purchaser.

Dimensions 13. The normal circumference conforming to the specified diameter shall be measured at a point $1\frac{23}{32}$ in. (43.65 mm.) from the gaging point on the throat of the flange. When measured on the circumference, wheels shall not vary more than $\frac{5}{16}$ in. above or below the normal size. Each wheel shall be so nearly circular that a true metallic ring, placed on its tread and bearing somewhere on the cone, shall, at no point, be more than $\frac{1}{32}$ in. from the tread. The thickness of the flange shall be determined by a minimum and maximum flange thickness gage which shall be regulated to not more than $\frac{1}{32}$ in. (0.794 mm.) over nor more than $\frac{1}{16}$ in. (1.59 mm.) under the normal flange thickness.

Taping. 14. All wheels shall be taped with a standard design of wheel circumference tape. The wheels shall have the figures 1, 2, 3, 4, and 5 cast on the back plate in $\frac{3}{16}$-in. (4.76 mm.) raised figures, $\frac{3}{4}$ in. in height and $\frac{1}{8}$ in. apart. The figure "3" shall represent normal tape size limited by $\frac{1}{16}$ in. (1.59 mm.) over or under the standard circumference (which for 33 in. (838.2 mm.) wheels will be 103.67 in. ± $\frac{1}{16}$ in. (2633.2 mm. ± 1.59 mm.)). The figure "1" shall represent the smallest diameter, and the figure "5" the largest diameter. When taping a wheel the figure representing the tape size shall be chipped off. Tape sizes shall either be stenciled in plain figures on the plate of the wheel or as may be otherwise designated by the purchaser.

Weights. 15. (*a*) If wheels are ordered in accordance with A.R.A. standard drawings the weights shall be as follows:

Maximum Gross Weight of Car,		Normal Weight of Wheel,		Minimum Weight of Wheel,	
lb.	kg	lb.	kg.	lb.	kg.
103 000	46 700	650	295	640	290
136 000	61 700	700	317	690	313
169 000	76 500	750	340	740	335
210 000	95 250	850	385	835	380

(*b*) In the case of wheels ordered with cores smaller in diameter than the standard, the additional weight shall be considered as additional to the normal weight given in the above table and shall be paid for by the purchaser.

(*c*) In any shipment where the average weight of wheels is above the normal weight given in the above table the excess weight shall be at the expense of the manufacturer.

FINISH

Surface Finish. 16. The body of the wheel shall be free from slag, shrinkage, or blow holes. The tread and throat shall be free from irregular wrinkles, slag, sand wash, chill cracks or sweat. Wheels will not be rejected on account of cracks around the circumference of the center core commonly known as "drawn hubs" or slight shrinkage holes on the face of the hub which will not interfere with the proper mounting of the wheels.

MARKING

Marking. 17. All wheels shall be marked and numbered consecutively in accordance with instructions issued by the purchaser. All wheels shall have plainly cast on the inside plate of the wheel the initials of the purchaser, the wheel number, weight of the wheel, and the month, day and year when cast. No wheels shall have duplicate numbers and all indistinct or duplicate numbers may be corrected only after having received the approval of the inspector. All wheels shall have the name of the manufacturer and the place of manufacture cast on the outside plate of the wheel.

INSPECTION AND REJECTION

Inspection. 18. The inspector representing the purchaser shall have free entry at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the wheels ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the wheels are being furnished in accordance with these specifications. All tests (except check analyses) and inspection shall be made at the place of manufacture prior to shipment, unless otherwise specified, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection and Retest.

19. (*a*) Should the test wheel selected for the drop test, thermal test, or chill test fail to conform to the requirements specified, all wheels bearing the same tape size shall be rejected (see Sections 8, 9 and 10). The inspector shall then select another wheel of a different tape size, which shall be submitted to the same test as the wheel which failed and if it passes the requirements of the test the remainder of the lot shall be accepted, provided the requirements of all other tests have been met.

(*b*) The numbers of all wheels which have been rejected because of failure to meet the requirements of the drop test, thermal test, or chill test shall be noted and such wheels shall not be submitted for test at any future time.

(*c*) *Individual Rejection.*—Individual wheels shall be rejected in accordance with the following:

(*1*) If they are under the minimum weight specified;
(*2*) If they have surface defects described in Section 16;
(*3*) If they are under the specified dimensions.

APPENDIX

As information of possible value to the users of these specifications, Committee A-3 on Cast Iron wishes to state that the Association of Manufacturers of Chilled Car Wheels has adopted recommended designs of chilled-tread car wheels of 24, 26, 28, 30, 33, 36, 39 and 42-in. diameter. The designs for the 33-in. diameter single plate wheels were approved in 1928 by the American Railway Association. The wheels for which designs have been made, the standard for maximum load and estimated weight of the wheels are given below:

Diameter of Wheel, in.	Standard for Maximum Load per Wheel, lb.	Estimated Weight, lb.	Diameter of Wheel, in.	Standard for Maximum Load per Wheel, lb.	Estimated Weight, lb.
24........	6 000	320	33........	12 875	650
24........	9 000	360	33........	17 000	700
24........	12 000	400	33........	21 125	750
24........	16 000	440	33........	26 250	850
26........	6 000	360	36........	16 000	800
26........	9 000	410	36........	20 000	860
26........	12 000	460	36........	25 000	980
26........	16 000	510	39........	16 000	875
28........	6 000	410	39........	20 000	950
28........	9 000	460	39........	25 000	1100
28........	12 000	510	42........	16 000	1000
28........	16 000	560	42........	20 000	1075
30........	6 000	485	42........	25 000	1225
30........	9 000	530			
30........	12 000	575			
30........	16 000	615			

TENTATIVE DEFINITIONS OF TERMS, WITH UNITS AND SYMBOLS, RELATING TO MAGNETIC TESTING[1]

A.S.T.M. Designation: A 127 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

In the following list of definitions the term defined is given first followed in parenthesis by any optional alternative terms which may be used when the context clearly indicates the intended conception. The symbol for the quantity is then given wherever such symbol is in use, followed by the definition of the standard term.

The name of the unit employed is included, together with the definition of the unit.

Basic Conceptions

Magnetic Field (*Field*).—The region in space in which a magnetic state exists.

UNIT: None.

Magnetic Circuit.—A closed path of magnetic flux.

Magnetic Flux (*Flux*), Φ.—The magnetic quantity which by its variation is capable of producing in an associated electric circuit an electromotive force proportional to its time rate of variation.

UNIT: *Maxwell.*—The maximum value of the magnetic flux, the uniform variation of which between zero and its full value in one second induces one c.g.s. unit of electromotive force in a single turn electric circuit enclosing the flux.

Magnetomotive Force, $\mathcal{F}$.—The total magnetizing influence acting on any part of a magnetic circuit.

UNIT: *Gilbert.*—The magnetomotive force resulting from a current in an electric circuit of any number of turns linked with the magnetic circuit when the product of the current in amperes by the number of turns is $\frac{1}{0.4\pi}$.

NOTE.—When a current of I amperes is flowing in a circuit of N turns, $\mathcal{F} = 0.4\pi NI$.

Derived Conceptions

Magnetic Force (*Magnetizing Force, Field Intensity*), H.—The space rate of variation of magnetomotive force at any point in the magnetic circuit.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. R. L. Sanford, Secretary of Committee A-6 on Magnetic Properties, U. S. Bureau of Standards, Washington, D. C.

UNIT: *Rowland.*—The magnetic force of one gilbert per centimeter.

NOTE.—At the center of an infinitely long solenoid having n turns per centimeter in which a current of I amperes is flowing, $H = 0.4 \pi n I$.

Magnetic Potential Difference.—The magnetomotive force between two points.

Induction (Flux Density), B.—The flux per unit area normal to the direction of the flux.

UNIT: *Gauss.*—An induction of one maxwell per square centimeter.

Normal Induction, B.—The induction in a magnetic material corresponding to a given magnetic force when the material is in a symmetrically cyclic magnetic condition with respect to the given magnetic force.

UNIT: Same as for *Induction.*

Intrinsic Induction (Ferric Induction), B_i.—The excess of the normal induction over that corresponding to the same magnetic force in empty space.

UNIT: Same as for *Induction.*

Saturation Induction, B_s.—The maximum intrinsic induction possible in a material.

UNIT: Same as for *Induction.*

Permeability, μ.—When used without a qualifying adjective, understood to be the normal permeability as defined below.

UNIT: None.

Normal Permeability, μ.—The ratio of the normal induction to the corresponding magnetic force.

UNIT: None.

Initial Permeability, μ_0.—The normal permeability when both the magnetic force and the induction are vanishingly small.

UNIT: None.

Differential Permeability, μ_d.—The ratio of the positive increase of normal induction to the positive increase of magnetic force when these increases are vanishingly small.

UNIT: None.

Incremental Permeability, μ_Δ.—The ratio of the cyclic change in induction to the corresponding cyclic change in magnetic force when the mean induction differs from zero.

UNIT: None.

Reversible Permeability, μ_r.—The incremental permeability when the change in induction is vanishingly small.

UNIT: None.

Intrinsic Permeability, μ_i.—The ratio of the intrinsic induction to the corresponding magnetic force.

UNIT: None.

Permeance, $\mathscr{P}$.—The property of any part of a magnetic circuit which determines the flux corresponding to a given magnetomotive force.

NOTE.—Permeance $= \frac{\Phi}{\mathscr{F}}$ equivalent to $\frac{\mu A}{l}$ for uniform μ.

where μ = permeability;
A = area in square centimeters; and
l = length in centimeters.

UNIT: None.

Reluctivity.—The reciprocal of permeability.

UNIT: None.

Reluctance, $\mathscr{R}$.—The reciprocal of permeance.

NOTE.—Reluctance $= \frac{\mathscr{F}}{\Phi} = \frac{l}{\mu A}$ for uniform μ.

UNIT: *Oersted*.—The reluctance of a portion of an empty space one centimeter in length and having a cross-section of one square centimeter.

Remanence.—The magnetic induction which remains in a magnetic circuit after the removal of an applied magnetic force.

NOTE.—If there is an air gap in the magnetic circuit, the remanence will be less than the residual induction.

UNIT: Same as for *Induction*.

Residual Induction, B_r.—The magnetic induction which remains in a magnetic material when the effective magnetic force has been reduced to zero.

NOTE.—When the material is in a symmetrically cyclic magnetic condition, the residual induction is called the *normal* residual induction.

UNIT: Same as for *Induction*.

Retentivity.—The property of a material measured by the normal residual induction remaining after the removal of an applied magnetic force corresponding to the saturation induction for the material.

UNIT: Same as for *Induction*.

Coercive Force, H_c.—The reversed magnetic force that is just sufficient to reduce the residual induction in a material to zero.

NOTE.—When the residual induction is the ***normal*** residual induction, the coercive force required is called the ***normal*** coercive force.

UNIT: Same as for *Magnetic Force.*

Coercivity.—The property of a material measured by the coercive force required to reduce to zero the induction remaining after the removal of an applied magnetic force corresponding to the saturation induction for the material.

UNIT: Same as for *Magnetic Force.*

Core Loss (*Iron Loss*), *W*.—The power expended in a magnetic material subjected to a varying induction.

Eddy Current Loss, W_e.—The part of the core loss due to currents circulating in the magnetic material as a result of electromotive forces induced by the varying induction.

Hysteresis Loss, W_h.—That part of the core loss due to so-called hysteresis effects.

Standard Core Loss, $W_{B/f}$.—The total power in watts per kilogram expended in the magnetic material which is subjected to a harmonically varying induction of a specified maximum value *B* and of a specified frequency *f*.

Aging (of magnetic materials).—The normal or accelerated change in magnetic properties of a magnetic material under continued normal or specified artificial aging conditions. When used in reference to core loss this term, unless otherwise modified, implies an increase in loss. When used in reference to permeability or remanence the term, in a positive sense, indicates a decrease in these quantities.

Dia-magnetic.—A descriptive term applied to a material, the permeability of which is less than unity.

Para-magnetic.—A descriptive term applied to a material, the permeability of which is slightly greater than unity and is approximately independent of the magnetic induction.

Ferro-magnetic.—A descriptive term applied to a material, the permeability of which is considerably greater than unity.

Linkage.—The product of the flux in maxwells by the number of turns in a coil or winding linked therewith.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-ALLOY (DURALUMIN) SHEET[1]

A.S.T.M. Designation: B 78 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

MANUFACTURE

Manufacture.

1. No scrap shall be used in the manufacture of aluminum-alloy (duralumin) sheet except such as shall accumulate at the manufacturer's plants from material of similar composition and of his own manufacture.

CHEMICAL COMPOSITION AND TESTS

Chemical Composition.

2. The sheet shall conform to the following requirements as to chemical composition:

Copper, per cent	3.5 to 4.5
Magnesium, per cent	0.2 to 0.75
Manganese, per cent	0.4 to 1.0
Aluminum, minimum, per cent	92

Chemical Analysis.

3. Samples for analysis shall be obtained from a random sheet representing each 500 lb. (226.8 kg.) or fraction thereof of aluminum alloy (duralumin), as mutually agreed upon between the manufacturer and the purchaser. Samples for analysis may be obtained from the tension or bend test specimens described in Section 6. The sample for analysis may be prepared by shearing or by drilling or by machining without the use of any lubricant in such a manner as to give a sample representative of the entire cross-section of the sheet. Samples so prepared shall be divided into three equal parts each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser and one for an umpire if necessary.

PHYSICAL PROPERTIES AND TESTS

Tensile Requirements.

4. (*a*) The sheet shall be supplied in the temper specified in the contract or purchase order and shall conform to the following requirements as to tensile properties for the specified temper:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Gann, Secretary of Committee B-7 on Light Metals and Alloys, Cast and Wrought, The Dow Chemical Co., Midland, Mich.

Thickness		Temper No. 1, Quenched and Aged			Temper No. 2, Annealed	
B. & S. Gage	Inch	Tensile Strength, minimum, lb. per sq. in.	Yield Point, minimum, lb. per sq. in.	Elongation in 2 in., minimum, per cent	Tensile Strength, maximum, lb. per sq. in.	Elongation in 2 in., minimum, per cent
No. 2 to 10	0.258 to 0.102	55 000	30 000	15	35 000	12
Thinner than No. 10 to No. 16	0.101 to 0.051	55 000	30 000	18	35 000	12
" " No. 16 to No. 20	0.050 to 0.032	55 000	30 000	18	35 000	12
" " No. 20 to No. 24	0.031 to 0.020	55 000	30 000	15	35 000	10
" " No. 24 to No. 28	0.020 to 0.013	55 000	30 000	15	35 000	8

(*b*) Tension test specimens for sheet in either of the tempers may be cut in any direction, irrespective of the direction of rolling.

Bend Tests.

5. Bend test specimens cut in any direction from aluminum-alloy (duralumin) sheet shall stand being bent cold through an angle of 180 deg. around a pin the diameter of which is equal to *n* times the thickness of the sheet without cracking; the values of *n* for Tempers Nos. 1 and 2 being as follows:

THICKNESS		VALUE OF *n*	
B. & S. GAGE	INCH	TEMPER NO. 1, QUENCHED AND AGED	TEMPER NO. 2, ANNEALED
No. 2 to No. 10	0.258 to 0.102	6	4
Thinner than No. 10 to No. 16	0.101 to 0.051	4	2
Thinner than No. 16 to No. 20	0.050 to 0.032	4	1
Thinner than No. 20 to No. 24	0.031 to 0.020	4	0
Thinner than No. 24 to No. 28	0.020 to 0.013	4	0

Number of Tests.

6. One tension and one bend test specimen shall be cut from a random sheet representing each 500 lb. (226.8 kg.) or fraction thereof of aluminum alloy (duralumin), as mutually agreed upon between the manufacturer and purchaser.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Thickness.

7. The thickness of sheets shall not vary from that specified by more than the following tolerances:

Thickness		Tolerances in Thickness		
B. & S. Gage	Inch	18 in. in Width and Wider	Over 18 to 36 in., inclusive, in Width	Over 36 in. in Width
Thicker than No. 11	0.092 and thicker	± 5 per cent of sheet thickness	± 5 per cent of sheet thickness	± 5 per cent of sheet thickness
No. 11 to No. 13	0.091 to 0.072	± 0.003 in.	± 0.003 in.	± 0.004 in.
No. 14 to No. 15	0.064 to 0.057	± 0.0025 in.	± 0.003 in.	± 0.004 in.
No. 16 to No. 18	0.051 to 0.040	± 0.002 in.	± 0.0025 in.	± 0.003 in.
No. 19 to No. 28	0.036 to 0.013	± 0.0015 in.	± 0.002 in.	± 0.0025 in.

WORKMANSHIP AND FINISH

8. All sheets shall be commercially flat and free from buckles, they shall be free from injurious surface defects and shall have a workmanlike finish. **Workmanship and Finish.**

INSPECTION AND REJECTION

9. The manufacturer shall afford the inspector representing the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. **Inspection.**

10. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified. **Rejection.**

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-MANGANESE ALLOY SHEET[1]

A.S.T.M. Designation: B 79 –30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. These specifications cover flat aluminum-manganese alloy sheet. Strip or coil sheet may show somewhat lower elongations than those specified but is required to conform to the requirements of the same bend test as the flat sheet.

MANUFACTURE

Manufacture. 2. No scrap shall be used in the manufacture of aluminum-manganese alloy sheet except such as shall accumulate at the manufacturer's plants from material of similar composition and of his own manufacture.

CHEMICAL COMPOSITION AND TESTS

Chemical Composition. 3. The sheet shall conform to the following requirements as to chemical composition:

Manganese, per cent	1.0 to 1.5
Copper, maximum, per cent	0.2
Aluminum, minimum, per cent	97.0

Chemical Analysis. 4. Samples for analysis shall be obtained from a random sheet representing each 500 lb. (226.8 kg.) or fraction thereof of aluminum-manganese alloy, as mutually agreed upon between the manufacturer and the purchaser. Samples for analysis may be obtained from the tension or bend test specimens described in Section 7. The sample for analysis may be prepared by shearing or by drilling or by machining without the use of any lubricant in such a manner as to give a sample representative of the entire cross-section of the sheet. Samples so prepared shall be divided into three equal parts each of which shall be placed in a sealed package, one for the manufacturer, one for the purchaser and one for an umpire if necessary.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Gann, Secretary of Committee B-7 on Light Metals and Alloys, Cast and Wrought, The Dow Chemical Co., Midland, Mich.

PHYSICAL PROPERTIES AND TESTS

Tensile Requirements.

5. (*a*) The sheet shall be supplied in the temper specified in the contract or purchase order and shall conform to the following requirements as to tensile properties for the specified temper:

Thickness		Temper No. 1, Soft		Temper No. 2, Half-Hard		Temper No. 3, Hard	
B. & S. Gage	Inch	Tensile Strength, minimum, lb. per sq. in.	Elongation in 2 in., minimum, per cent	Tensile Strength, minimum, lb. per sq. in.	Elongation in 2 in., minimum, per cent	Tensile Strength, minimum, lb. per sq. in.	Elongation in 2 in., minimum, per cent
No. 2 to No. 16	0.258 to 0.051	14 500	25	19 500	6	.....	.
Thinner than No. 10 to No. 16	0.102 to 0.051	.....	..	.....	.	27 000	4
" " No. 16 to No. 20	0.050 to 0.032	14 500	23	19 500	5	27 000	3
" " No. 20 to No. 24	0.031 to 0.020	14 500	20	19 500	4	30 000	2
" " No. 24 to No. 28	0.019 to 0.013	14 500	20	19 500	3	33 000	1

(*b*) Tension test specimens for sheet in Temper No. 2, Half-Hard, shall be cut from the sheet parallel to the direction of final rolling. From sheet in Temper No. 1, Soft, or Temper No. 3, Hard, the tension test specimens may be cut in any direction.

Bend Tests.

6. (*a*) Bend test specimens cut in any direction from sheet in Temper No. 1, Soft, shall stand being bent cold through 180 deg. flat upon themselves without cracking.

(*b*) Bend test specimens cut in any direction from sheet in Temper No. 2, Half-Hard shall stand being bent cold through 180 deg. around a pin the diameter of which is equal to twice the thickness of the sheet.

(*c*) The bend test shall not be required on sheet in Temper No. 3, Hard.

Number of Tests.

7. One tension and one bend test specimen shall be cut from a random sheet representing each 500 lb. (226.8 kg.) or fraction thereof of aluminum-manganese alloy as mutually agreed upon between the manufacturer and purchaser.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Thickness.

8. The thickness of sheets shall not vary from that specified by more than the following tolerances:

Thickness		Tolerances in Thickness, in.		
B. & S. Gage	Inch	20 in. in Width and Under	Over 20 to 36 in., inclusive, in Width	Over 36 to 60 in., inclusive, in Width
No. 2 to No. 3	0.258 to 0.229	± 0.007	± 0.008	± 0.009
Thinner than No. 3 to No. 9	0.228 to 0.114	± 0.005	± 0.006	± 0.007
" " No. 9 to No. 13	0.113 to 0.072	± 0.003	± 0.0035	± 0.004
" " No. 13 to No. 21	0.071 to 0.028	± 0.0025	± 0.0025	± 0.003
" " No. 21 to No. 24	0.027 to 0.020	± 0.002	± 0.002	± 0.003
" " No. 24 to No. 27	0.019 to 0.014	± 0.002	± 0.002	± 0.002
" " No. 27	0.013 and less	± 0.0015	± 0.0015	± 0.0015

WORKMANSHIP AND FINISH

Workmanship and Finish. 9. All sheets shall be commercially flat and free from buckles; they shall be free from injurious surface defects and shall have a workmanlike finish.

INSPECTION AND REJECTION

Inspection. 10. The manufacturer shall afford the purchaser, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications.

Rejection. 11. Material which fails to conform to these specifications will be rejected and the manufacturer shall be notified.

EXPLANATORY NOTES

In the case of sheet in the half-hard temper, there is an appreciable difference in the elongation depending upon the direction in which the test specimen is taken from the sheet. This measurement made parallel to the direction of final rolling is distinctly higher than if the specimen were cut perpendicular to this direction. This difference is not observed in hard or soft sheet. The inspection of half-hard sheet calls for the use of specimens parallel to the direction of final rolling because of the greater contrast with the values obtained from hard sheet. The fact that the bend test specimens may be taken without regard to the direction of rolling is evidence that the lower elongation across the grain does not indicate a lack of workability.

The use of grips which insure a uniform axial loading of the test specimen is essential, if satisfactory results are to be obtained.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-BASE CASTING ALLOYS IN INGOT FORM[1]

A.S.T.M. Designation: B 58 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1930.[2]

Scope. 1. These specifications cover commercial aluminum-base casting alloys in ingot form for remelting. The specific gravity of these alloys does not exceed 3.0. Eleven alloys are specified and are designated Alloys A to K, inclusive (see Explanatory Notes).

MANUFACTURE

Process. 2. The alloys may be made by any approved process.

Quality. 3. The material covered by these specifications shall be of uniform quality, and shall be free from dross, slag and other harmful contamination.

CHEMICAL COMPOSITION AND TESTS

Chemical Composition 4. The alloys shall conform to the requirements as to chemical composition specified in Table I.

Sampling. 5. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the ingot, and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Gann, Secretary of Committee B-7 on Light Metals and Alloys, Cast and Wrought, The Dow Chemical Co., Midland, Mich.

By adoption of these specifications, the Society does not undertake to insure any one utilizing such specifications against liability for infringement of any patent or assume any such liability, and such adoption does not constitute a recommendation of any patented or proprietary application that may be involved.

These tentative specifications, together with the Tentative Specifications for Aluminum-Base Alloy Castings (A.S.T.M. Designation: B 26 – 30 T), see p. 997, are in effect a revision of the former Standard Specifications for Light Aluminum Casting Alloys (A.S.T.M. Designation: B 26 – 21), which standard specifications were accordingly discontinued in 1927.

[2] Latest revision approved by Committee E–10 on Standards, August 12, 1930.

INSPECTION AND REJECTION

Inspection. 6. (*a*) Inspection may be made at the manufacturer's works where the alloys are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

TABLE I.—CHEMICAL COMPOSITIONS OF ALUMINUM-BASE CASTING ALLOYS.

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Manganese, maximum, per cent	Zinc, maximum, per cent	Other Impurities, maximum, per cent	Remarks
A....	Remainder	7 to 8.5	1 max.	0.5 max.	trace	0.3	0.2	0.3	Total of all constituents other than aluminum and copper not to exceed 1.7 per cent.
B....	Remainder	7 to 8.5	0.8 to 1.2	1 to 1.5	trace	0.3	0.2	0.3	
C....	Remainder	6 to 8	1.3 max.	1 max.	....	...	2.5	1	
D...	Remainder	6 to 8	1 max.	2 to 3	....	...	1.5	0.5	
E....	Remainder	11 to 13	1 max.	1 max.	trace	0.3	0.2	0.3	
F....	Remainder	9.25 to 10.75	1.3 max.	...	0.15 to 0.35	0.2	0.2	...	Iron plus silicon not to exceed 2 per cent.
G....	Remainder	4 to 5	1 max.	1.2 max.	0.3 max.	0.3	0.2	0.2	Total of all constituents other than aluminum and copper not to exceed 2.5 per cent.
H...	Remainder	3.5 to 4.5	0.8 max.	0.7 max.	1.2 to 1.7	...	0.1	0.2	Nickel 1.8 to 2.3 per cent.
I....	Remainder	0.6 max.	0.8 max.	4.5 to 6	trace	0.3	0.2	0.3	
J....	Remainder	0.3 max.	0.6 max.	12 to 13	trace	0.5	0.2	0.3	
K...	88 min.	3 to 4	0.8 max.	7 to 9	trace	0.3	0.2	0.3	

Rejection. 7. Material which does not conform to the requirements of these specifications may be rejected, and if rejected shall be replaced by the manufacturer without charge to the purchaser. The full weight of the rejected material shall be returned to the manufacturer.

Explanatory Notes

Alloy A.—Alloy A has a specific gravity of about 2.83. In pattern design a shrinkage of about 0.156 ($\frac{5}{32}$) in. per foot should be allowed. This alloy was for years the standard and is still somewhat used but is being superseded by Alloy B.

Alloy B.—Alloy B has approximately the same specific gravity and shrinkage as Alloy A. It is superseding Alloy A as it possesses better casting characteristics, especially in the more difficult work where higher pouring temperatures than those usually employed are found necessary. The tendency towards cracks and shrinkage is considerably overcome by the careful control of the iron and silicon contents. This alloy is used for general casting purposes.

Alloy C.—The specific gravity of Alloy C is about 2.83 to 2.86. The pattern shrinkage is about 0.156 ($\frac{5}{32}$) in. per foot. It has somewhat better machining qualities than Alloys A and B. It is used for about the same purposes as Alloy B, particularly for automotive work, such as crank and transmission cases and similar parts.

Alloy D.—Alloy D is very similar to Alloy C in both properties and uses. Due to its higher silicon content it has greater fluidity and is less subject to cracking. It is used for the more intricate general casting work.

Alloy E.—Alloy E has a specific gravity of about 2.95 and the pattern shrinkage is 0.156 ($\frac{5}{32}$) in. per foot. It is used for pumps, manifolds, and general castings which should be leak proof. The high copper content makes the alloy more brittle and lowers its shock resistance.

Alloy F.—The specific gravity of Alloy F is about 2.90 and the pattern shrinkage about 0.156 ($\frac{5}{32}$) in. per foot. eThe alloy isused for pistons, valve guides, and bearings or other parts where hardness and good bearing qualities are essential.

Alloy G.—Alloy G has a specific gravity of about 2.78. It is for general casting purposes where lightness and higher strengths are desired. It is more resistant to corrosion than the other copper alloys. The various strengths are obtained through different heat treatments. Heat treatment No. 1 gives maximum elongation and resistance to shock. It is a solution heat treatment and may be specified where the most rugged service is required. An aging effect takes place on standing which increases the strength and slightly decreases the elongation. Heat treatment No. 2 is a solution and precipitation heat treatment, and should be specified where a higher initial strength, yield point, and hardness are desired. Heat treatment No. 3 should be specified where the highest strength is desired. This alloy is used in general for high-strength parts in street cars and busses, parts for internal combustion engines, outboard motor parts and other marine castings.

Alloy H.—The specific gravity of Alloy H is 2.80. It is usually used in the heat-treated condition. It has advantage over the copper alloys of retaining more of its strength at elevated temperatures. This property makes the alloy useful for aircraft cylinder heads and pistons.

Alloy I.—Alloy I is somewhat lighter than aluminum, having a specific gravity of 2.69. It withstands corrosion better than the copper alloys. The free flowing property of the alloy when molten makes it easier to pour castings of thin section or intricate design. It has a lower strength and yield point than the copper alloys and poorer machining qualities. It is especially suitable for automobile body parts, cooking utensils, and marine castings.

Alloy J.—The specific gravity of Alloy J is 2.68. Immediately before pouring, the alloy is treated by a process called "modification." Its corrosion resistance is good, especially to salt water. It has good foundry characteristics and can be used for castings having both thin and heavy sections. It is not as readily machined and has a lower yield point in proportion to tensile strength than most of the copper alloys. It is used for architectural and marine castings, bus, street car, and engine parts, and for thin castings such as radiators, small motor housings and meter cases.

Alloy K.—Alloy K has good casting characteristics and a higher yield point than the silicon alloys without copper. It is used more extensively for match plate and pattern work.

TENTATIVE SPECIFICATIONS
FOR
ALUMINUM-BASE ALLOY CASTINGS[1]

A.S.T.M. Designation: B 26 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1924; REVISED, 1925, 1926, 1930.[2]

Scope. 1. These specifications cover commercial aluminum-base alloy castings having a specific gravity of three and less. Eleven alloys are specified and are designated Alloys A to K, inclusive (see Note 1).

MANUFACTURE

Process. 2. The alloy may be made by any approved method.

CHEMICAL COMPOSITION AND TESTS

Chemical Composition 3. The alloys shall conform to the requirements as to chemical composition specified in Table I (see Note 1).

Sampling. 4. (*a*) The sample for chemical analysis may be taken either by sawing, drilling or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation, and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of iron introduced in taking the sample.

PHYSICAL PROPERTIES AND TESTS

Tension Tests. 5. The alloys shall conform to the minimum requirements as to tensile properties specified in Table II (see Note 2).

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Gann, Secretary of Committee B-7 on Light Metals and Alloys, Cast and Wrought, The Dow Chemical Co., Midland, Mich.

By adoption of these specifications, the Society does not undertake to insure any one utilizing such specifications against liability for infringement of any patent or assume any such liability, and such adoption does not constitute a recommendation of any patented or proprietary application that may be involved.

These tentative specifications, together with the Tentative Specifications for Aluminum-Base Sand-Casting Alloys in Ingot Form (A.S.T.M. Designation: B 58 – 30 T), see p. 993, are in effect a revision of the former Standard Specifications for Light Aluminum Casting Alloys (A.S.T.M. Designation: B 26 – 21), which standard specifications were accordingly discontinued in 1927.

[2] Latest revision approved by Committee E-10 on Standards, August 12, 1930.

TABLE I.—CHEMICAL COMPOSITIONS OF ALUMINUM-BASE ALLOY CASTINGS.

Alloy	Aluminum, per cent	Copper, per cent	Iron, per cent	Silicon, per cent	Magnesium, per cent	Manganese, maximum, per cent	Zinc, maximum, per cent	Other Impurities, maximum, per cent	Remarks
A....	Remainder	7 to 8.5	1.2 max.	0.5 max.	trace	0.3	0.2	0.3	Total of all constituents other than aluminum and copper not to exceed 1.7 per cent.
B....	Remainder	7 to 8.5	0.8 to 1.4	1 to 1.5	trace	0.3	0.2	0.3	
C....	Remainder	6 to 8	1.5 max.	1 max.	....	...	2.5	1	
D...	Remainder	6 to 8	1.2 max.	2 to 3	....	...	1.5	0.5	
E....	Remainder	11 to 13	1.2 max.	1 max.	trace	0.3	0.2	0.3	
F....	Remainder	9.25 to 10.75	1.5 max.	...	0.15 to 0.35	0.2	0.2	...	Iron plus silicon not to exceed 2 per cent
G ...	Remainder	4 to 5	1.2 max.	1.2 max.	0.3 max.	0.3	0.2	0.2	Total of all constituents other than aluminum and copper not to exceed 2.5 per cent.
H...	Remainder	3.5 to 4.5	1 max.	0.7 max.	1.2 to 1.7	...	0.1	0.2	Nickel 1.8 to 2.3 per cent.
I....	Remainder	0.6 max.	1 max.	4.5 to 6	trace	0.3	0.2	0.3	
J...	Remainder	0.3 max.	0.8 max.	12 to 13	trace	0.5	0.2	0.3	
K...	88 min.	3 to 4	1 max.	7 to 9	trace	0.3	0.2	0.3	

TABLE II.—PHYSICAL PROPERTIES OF ALUMINUM-BASE ALLOY CASTINGS.

ALLOY		TENSILE STRENGTH, MINIMUM, LB. PER SQ. IN.	ELONGATION IN 2 IN., MINIMUM, PER CENT
A		18 000	....
B		19 000	....
C		19 000	....
D		18 000	....
E		19 000	....
F		19 000	....
G....	Heat Treatment No. 1[a]	28 000	6
	Heat Treatment No. 2[a]	30 000	3
	Heat Treatment No. 3[a]	36 000	0
H...	Heat Treated[b]	32 000	....
I		16 000	3
J		24 000	5
K		....	....

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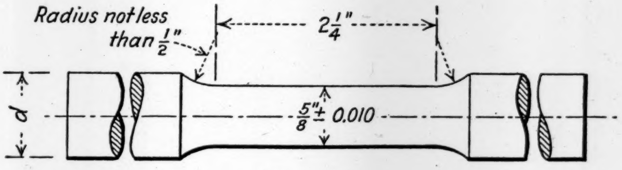
[a] See Note 1, Alloy G.

[b] See Note 1, Alloy H.

Test Specimens.

6. (*a*) Two test bars shall be an integral part of large castings, or cast separately in the case of small castings to represent a lot or melt, and shall be molded in a manner similar to the castings which they represent. If the castings are heat treated, the test bars representing such castings shall be similarly heat treated.



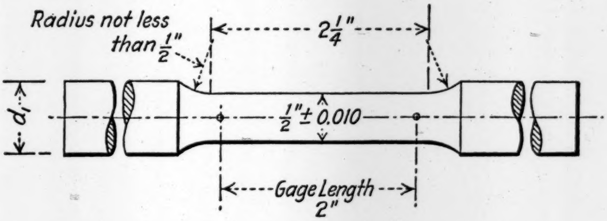
NOTE:

The Gage Length, Parallel Section and Fillets shall be as shown, but the Ends may be of any Shape to permit of Machining according to the Requirements of Fig. 2.

In Order to promote the Breaking of the Specimen in the Center it is permissible to use a Taper in the Reduced Section from the Fillets to the Center of not to exceed 0.010 in.

It is recommended, that Diameter d be from $\frac{7}{8}$" to $1\frac{1}{8}$".

FIG. 1.



NOTE:

The Gage Length, Parallel Section and Fillets shall be as shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a way, that the Load shall be Axial.

In Order to promote the Breaking of the Specimen in the Center it is permissible to use a Taper in the Reduced Section from the Fillets to the Center of not to exceed 0.010 in.

It is recommended, that Diameter d_1 be from $\frac{3}{4}$" to 1."

FIG. 2.

(*b*) The manufacturer and purchaser shall agree whether the test bars can be attached to castings, on the locations of the bars, on the castings to which bars are to be attached, on the method of casting unattached bars and whether a "cast-to-size bar" or a "machined-to-size bar" shall be used (see Note 2).

(*c*) The "machined-to-size bar" shall be cast according to the dimensions shown in Fig. 1, and machined to conform to the dimensions shown in Fig. 2. The "cast-to-size" bar shall be cast according to the dimensions shown in Fig. 2 and shall be tested without machining. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial (see Note 3).

Number of Tests.

7. (*a*) Tests shall as far as possible be made by heats or melts, but unless otherwise agreed upon, two tension tests shall be made upon each unit lot of 500 lb. or single delivery of less than 500 lb.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser or his representative shall agree upon the selection of another specimen in its stead.

INSPECTION AND REJECTION

Inspection.

8. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

9. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected shall be replaced by the manufacturer without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

EXPLANATORY NOTES

NOTE 1.—*Alloy A.*—Alloy A has a specific gravity of about 2.83. In pattern design a shrinkage of about 0.156 ($\frac{5}{32}$) in. per foot should be allowed. This alloy was for years the standard and is still somewhat used but is being superseded by Alloy B.

Alloy B.—Alloy B has approximately the same specific gravity and shrinkage as Alloy A. It is superseding Alloy A as it possesses better casting characteristics, especially in the more difficult work where higher pouring temperatures than those usually employed are found necessary. The tendency towards cracks and shrinkage is considerably overcome by the careful control of the iron and silicon contents. This alloy is used for general casting purposes.

Alloy C.—The specific gravity of Alloy C is about 2.83 to 2.86. The pattern shrinkage is about 0.156 ($\frac{5}{32}$) in. per foot. It has somewhat better machining qualities than Alloys A and B. It is used for about the same purposes as Alloy B, particularly for automotive work, such as crank and transmission cases and similar parts.

Alloy D.—Alloy D is very similar to Alloy C in both properties and uses. Due to its higher silicon content it has greater fluidity and is less subject to cracking. It is used for the more intricate general casting work.

Alloy E.—Alloy E has a specific gravity of about 2.95 and the pattern shrinkage is 0.156 ($\frac{5}{32}$) in. per foot. It is used for pumps, manifolds, and general castings which should be leak proof. The high copper content makes the alloy more brittle and lowers its shock resistance.

Alloy F.—The specific gravity of Alloy F is about 2.90 and the pattern shrinkage about 0.156 ($\frac{5}{32}$) in. per foot. The alloy is used for pistons, valve guides, and bearings or other parts where hardness and good bearing qualities are essential.

Alloy G.—Alloy G has a specific gravity of about 2.78. It is for general casting purposes where lightness and higher strengths are desired. It is more resistant to corrosion than the other copper alloys. The various strengths are obtained through different heat treatments. Heat treatment No. 1 gives maximum elongation and resistance to shock. It is a solution heat treatment and may be specified where the most rugged service is required. An aging effect takes place on standing which increases the strength and slightly decreases the elongation. Heat treatment No. 2 is a solution and precipitation heat treatment, and should be specified where a higher initial strength, yield point, and hardness are desired. Heat treatment No. 3 should be specified where the highest strength is desired. This alloy is used in general for high-strength parts in street cars and busses, parts for internal combustion engines, outboard motor parts and other marine castings.

Alloy H.—The specific gravity of Alloy H is 2.80. It is usually used in the heat-treated condition. It has advantage over the copper alloys of retaining more of its strength at elevated temperatures. This property makes the alloy useful for aircraft cylinder heads and pistons.

Alloy I.—Alloy I is somewhat lighter than aluminum, having a specific gravity of 2.69. It withstands corrosion better than the copper alloys. The free flowing property of the alloy when molten makes it easier to pour castings of thin section or intricate design. It has a lower strength and yield point than the copper alloys and poorer machining qualities. It is especially suitable for automobile body parts, cooking utensils, and marine castings.

Alloy J.—The specific gravity of Alloy J is 2.68. Immediately before pouring, the alloy is treated by a process called "modification." Its corrosion resistance is good, especially to salt water. It has good foundry characteristics and can be used for castings having both thin and heavy sections. It is not as readily machined and has a lower yield point in proportion to tensile strength than most of the copper alloys. It is used for architectural and marine castings, bus, street car, and engine parts, and for thin castings such as radiators, small motor housings and meter cases.

Alloy K.—Alloy K has good casting characteristics and a higher yield point than the silicon alloys without copper. It is used more extensively for match plate and pattern work.

NOTE 2.—Some latitude has been allowed in the matter of test specimens; test bars "cast to size" are stronger than those which are "machined to size" and the tensile properties specified are regularly obtained in commercial production only with the "cast-to-size" bar. When "machined-to-size" specimens are required to meet the values given in these specifications, rejections may be expected to run higher than those experienced in usual commercial production. Owing to insufficient information being available on the tensile properties of "machined-to-size" specimens it was not possible to include a separate table of values for this type of specimen.

NOTE 3.—It is strongly recommended that a self-centering form of tension test specimen holder be used. Most aluminum alloys are brittle and give lower and less uniform test results when tested in ordinary wedge grips without centering.

TENTATIVE SPECIFICATIONS
FOR
MAGNESIUM-BASE ALLOY CASTINGS[1]

A.S.T.M. Designation: B 80 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1930.

Scope. 1. These specifications cover commercial magnesium-base alloy sand castings having a specific gravity of 1.9 or less. Three typical alloys are specified and are designated Alloys Nos. 1, 2 and 3.

Note.—Alloy No. 1 is the most widely used alloy, and is recommended for general casting work.

Alloy No. 2 possesses a higher yield point and greater hardness. Considerable latitude has been allowed in the chemical composition, as similar properties in the cast alloys can be obtained from different compositions. The copper content should be kept low where maximum corrosion resistance is desired.

Alloy No. 3 has a thermal conductivity 50 to 75 per cent greater than Alloys Nos. 1 and 2, and is recommended where this property is of great importance.

MANUFACTURE

Process. 2. The alloy may be made from virgin metal or from purified scrap metal of known composition.

Heat Treatment 3. Castings made from Alloy No. 1 may be subjected to such heat treatment as the manufacturer desires to produce material that will conform to the requirements specified. Heat treatment shall be performed on the whole of a casting, never on a part only, and shall be applied in a manner that will produce the utmost uniformity.

CHEMICAL COMPOSITION

Chemical Composition. 4. The alloys shall conform to the following requirements as to chemical composition:

Alloy	Magnesium, minimum, per cent	Aluminum, per cent	Manganese, minimum, per cent	Copper, per cent	Cadmium, per cent	Silicon, maximum, per cent	Remarks
No. 1....	90	5.5 to 8.5	0.2	0.1, max.	1.0, max.	0.2	Other metals, 0.3 per cent, maximum
No. 2...	87	8 to 12	0.1	2.5, max.	...	0.2	Other metals, 2.5 per cent, maximum
No. 3....	91	1.7 to 2.3	0.2	3.5 to 4.5	1.6 to 2.4	0.2	Other metals, 0.3 per cent, maximum

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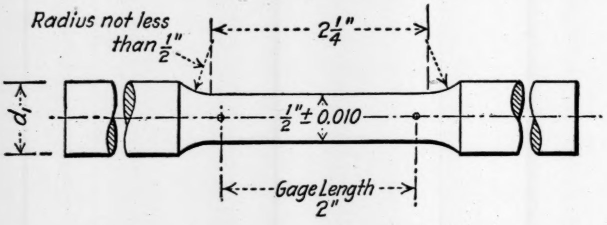
[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Gann, Secretary of Committee B-7 on Light Metals and Alloys, Cast and Wrought, The Dow Chemical Co., Midland, Mich.

Chemical Analysis. 5. (*a*) The sample for chemical analysis may be taken either by sawing, drilling, or milling the casting or tension test specimen and shall represent the average cross-section of the piece.

(*b*) The saw, drill, cutter, or other tool shall be thoroughly cleaned. No lubricant should be used in the sampling operation.



NOTE:

The Gage Lengtn, Parallel Section and Fillets shall be as shown, but the Ends may be of any Shape to fit the Holders of the Testing Machine in such a way, that the Load shall be Axial.

In Order to promote the Breaking of the Specimen in the Center it is permissible to use a Taper in the Reduced Section from the Fillets to the Center of not to exceed 0.010 in.

It is recommended, that Diameter d_1 be from $\frac{3}{4}$" to 1."

FIG. 1.—Tension Test Specimen.

PHYSICAL PROPERTIES AND TESTS

Tensile Requirements. 6. The castings shall conform to the following requirements as to tensile properties:

ALLOY	CONDITION	TENSILE STRENGTH, MINIMUM, LB. PER SQ. IN.	ELONGATION IN 2 IN., MINIMUM, PER CENT
No. 1	Sand Cast	24 000	4
	Sand Cast, Heat Treated	29 000	6
No. 2	Sand Cast	20 000	0.5
No. 3	Sand Cast	21 000	2

Test Specimens. 7. The test bars shall be separately cast in green sand and shall be "cast to size" according to the dimensions shown in Fig. 1. They shall not be machined prior to test except to adapt the grips to the holders of the testing machine in such a manner as to insure an axial load.

Number of Tests. 8. (*a*) The tests shall, so far as possible, be made by heats or melts, but unless otherwise agreed upon, two tension tests shall be made for each unit of 500 lb. or fraction thereof.

(*b*) If any test specimen shows defective machining or develops flaws, it may be discarded; in which case the manufacturer and the purchaser, or his representative, shall agree upon the selection of another specimen in its stead.

WORKMANSHIP AND FINISH

Workmanship and Finish.

9. The castings shall be of uniform quality and condition, free from cracks or other injurious defects, and shall be well cleaned before inspection by sand-blasting, tumbling, chipping, pickling in sulfuric acid, or other approved process.

INSPECTION AND REJECTION

Inspection.

10. (*a*) Inspection may be made at the manufacturer's works where the castings are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have the inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspecter, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

Rejection.

11. Castings which show injurious defects revealed by machining operations subsequent to acceptance may be rejected, and if rejected shall be replaced by the manufacturer without charge to the purchaser. The full weight of the original material rejected shall be returned to the manufacturer.

TENTATIVE SPECIFICATIONS
FOR
COPPER-BASE ALLOYS IN INGOT FORM FOR SAND CASTINGS[1]

A.S.T.M. Designation: B 30 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED AS TENTATIVE, 1919; ADOPTED IN AMENDED FORM, 1922;
REISSUED AS TENTATIVE, 1928; REVISED, 1930.[2]

Scope.

1. These specifications cover brass ingot metal for sand castings in fifteen different compositions, regularly sold by the trade and arbitrarily herein given numbers 1 to 15 inclusive to differentiate them from one another. These numbers have no other significance.

MANUFACTURE

Quality.

2. The manufacturer shall use care to have each lot of ingot metal as uniform in quality as possible. This metal may be manufactured by any refining process which will yield a satisfactory quality of product.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition.

3. The alloys shall conform to the requirements as to chemical composition given in Table I, within the limits specified therein.

NOTE.—The limits specified in Table I indicate the maximum and minimum percentages within which variations of different elements shall be permitted, with the understanding that every precaution shall be taken both in the selection of raw materials as well as methods of manufacture to insure that the resulting ingot metal will come within these specified limits.

Samples for Chemical Analysis.

4. (*a*) Ten ingots shall be selected by the inspector to represent each 40,000 lb. and five ingots shall be selected for less than carload lots.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. D. K. Crampton, Secretary of Committee B-5 on Copper and Copper Alloys, Chase Metal Works, Waterbury, Conn.

These tentative specifications are, in effect, a revision of the former Standard Specifications for Brass Ingot Metal, Graded and Ungraded, for Sand Castings (A.S.T.M. Designation: B 30 – 22), which specifications were discontinued in 1928.

[2] Latest revision approved by Committee E-10 on Standards, August 12, 1930.

(*b*) The samples for chemical analysis may be taken either by sawing, drilling or milling the ingots and shall represent the average cross-section of all of the ingots selected for sampling.

(*c*) The saw, drill, cutter or other tool used shall be thoroughly cleaned. No lubricant shall be used in the operation and the sawings or metal chips shall be carefully treated with a magnet to remove any particles of steel introduced in taking the sample.

Methods of Chemical Analysis. 5. The chemical analysis shall be made in accordance with the Standard Methods of Chemical Analysis of Brass Ingots and Sand Castings (A.S.T.M. Designation: B 45) of the American Society for Testing Materials.[1]

TABLE I.—CHEMICAL COMPOSITIONS OF COPPER-BASE ALLOYS.

Alloy	Copper, per cent	Lead, per cent	Tin, per cent	Zinc, per cent	Impurities, maximum, per cent							Total Constituents, per cent	
					Antimony	Iron	Nickel	Phosphorus	Sulfur	Aluminum	Silicon	Other than Copper, Lead, Tin, Zinc and Nickel	Other than Copper, Lead, Tin, Zinc, Nickel and Antimony
No. 1	Remainder	1.50 to 2.50	9 to 11	1.50 to 2.50	0.25	0.25	0.50	0.03	0.08	0.005	0.05	0.50	....
No. 2	Remainder	1.50 to 2.50	7.25 to 8.75	3.50 to 4.50	0.25	0.25	0.50	0.03	0.08	0.005	0.05	0.50	....
No. 3	Remainder	4.25 to 5.75	5.25 to 6.75	2.50 to 3.50	0.25	0.25	0.50	0.03	0.08	0.005	0.05	0.50	....
No. 4	Remainder	4.25 to 5.75	4.25 to 5.75	4.25 to 5.75	0.25	0.25	0.50	0.03	0.08	0.005	0.05	0.50	....
No. 5	Remainder	4.25 to 5.75	3.25 to 4.75	9 to 11	0.25	0.35	0.50	0.03	0.08	0.005	0.05	0.50	....
No. 6	Remainder	7 to 9	2.50 to 3.50	8.50 to 11.50	0.25	0.35	0.50	0.03	0.08	0.005	0.03	0.50	....
No. 7	Remainder	9 to 11	9 to 11	1.00[a]	1.00	0.25	0.50	0.05	0.08	0.005	0.03	....	0.50
No. 8	Remainder	9 to 11	9 to 11	2.00[a]	1.00	0.25	0.50	0.05	0.08	0.005	0.03	....	0.50
No. 9	Remainder	13.50to16.50	7 to 9	2.00[a]	1.00	0.25	0.50	0.05	0.08	0.005	0.03	....	0.50
No. 10	Remainder	18 to 22	5.25 to 6.75	1.50[a]	1.00	0.25	0.50	0.05	0.08	0.005	0.03	....	0.50
No. 11	Remainder	14 to 20	3.50 to 5.50	4 to 6	1.00	0.25	0.50	0.05	0.08	0.005	0.03	....	0.50
No. 12	70 to 75	1 to 4	2.00[a]	Remainder	0.10	0.25	0.50	0.01	0.05	0.005	0.10	0.50	....
No. 13	67 to 70	1 to 4	1.50[a]	Remainder	0.10	0.30	0.50	0.01	0.05	0.005	0.10	0.55	....
No. 14	64 to 67	1 to 3	1.00[a]	Remainder	0.10	0.35	0.50	0.01	0.05	0.005	0.10	0.60	....
No. 15	60[b]	3.00[a]	1.00[a]	Remainder	0.10	0.35	0.50	0.01	0.05	0.50	0.10	1.00	....

[a] Maximum.
[b] Minimum.

Marking. 6. The designating mark of the manufacturer, the proper lot number, and the numerical designation of the alloy shall be marked on each ingot for identification.

INSPECTION AND REJECTION

Inspection. 7. (*a*) Inspection may be made at the manufacturer's works, where the ingots are made, or at the point at which they are received, at the option of the purchaser.

(*b*) If the purchaser elects to have inspection made at the manufacturer's works, the inspector representing the purchaser shall have free entry, at all times while work on the contract of the purchaser is being performed, to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with these specifications. All tests and inspection shall be so conducted as not to interfere unnecessarily with the operation of the works.

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 837.

Rejection. 8. If the test ingots selected to represent a lot fail to conform to the requirements specified in Section 3 all ingots in such lot shall be rejected.

CLAIMS

Claims. 9. Claims, to be considered, shall be made in writing within 30 days of receipt of material at the purchaser's plant and the results of the purchaser's tests shall be given. The manufacturer shall, within one week of receipt of such claim, either agree to satisfy the claim, or send a representative to the purchaser's plant to resample the shipment in accordance with Section 4. Samples so taken shall be sealed and submitted to a mutually agreeable umpire whose determinations shall be final.

Settlement of Claims. 10. The expense of umpire analysis shall be paid by the loser or divided in proportion to the concession made in case of a compromise. In case of rejection being established, the damages shall be limited to the payment of freight both ways by the manufacturer for the substitution of an equivalent weight of ingot metal conforming to these specifications.

APPENDIX

The data in the following tables do not constitute a part of these specifications. They are given merely to indicate to the purchaser the physical properties of the various alloys specified, that may be expected of carefully manufactured alloys of the formulas indicated and to constitute a guide to the purchaser in selecting the alloy best suited for meeting the service conditions for which the ingot metal is to be used.

Alloy	Tensile Strength, lb. per sq. in.[a]	Elongation in 2 in., per cent	Reduction of Area, per cent	Compression Deformation Limit, lb. per sq. in.[b]	Brinell Hardness Number, (500 kg. for 30 sec.)	Shrinkage, in. per ft.	Weight, lb. per cu. ft.
No. 1	32 000 - 38 000	15 - 20	15 - 20	......	55 - 65	0.125	535
No. 2	30 000 - 36 000	25 - 30	25 - 30	......	55 - 65	0.125	535
No. 3	25 000 - 33 000	15 - 20	15 - 20	......	45 - 60	0.140	535
No. 4	27 000 - 33 000	15 - 20	15 - 20	......	50 - 60	0.140	535
No. 5	29 000 - 35 000	25 - 35	20 - 30	......	40 - 50	0.140	535
No. 6	22 000 - 28 000	10 - 15	10 - 15	......	50 - 55	0.125	540
No. 7	27 000 - 33 000	7 - 12	8 - 13	12 500	47 - 52	0.25	553
No. 8	27 000 - 33 000	7 - 10	7 - 12	12 500	47 - 52	0.25	553
No. 9	25 000 - 30 000	11 - 17	10 - 16	12 000	45 - 50	0.25	570
No. 10	22 000 - 27 000	10 - 16	7 - 13	11 000	42 - 47	0.25	570
No. 11	25 000 - 30 000	10 - 15	7 - 13	12 000	47 - 52	0.25	570
No. 12	30 000 - 35 000	35 - 45	25 - 35	......	40 - 50	0.125	535
No. 13	30 000 - 35 000	25 - 35	20 - 30	......	40 - 50	0.125	534
No. 14	30 000 - 35 000	25 - 35	20 - 30	......	40 - 50	0.125	533
No. 15	30 000 - 45 000	15 - 25	20 - 30	......	40 - 50	0.20	500

[a] The tension tests were made on test specimens taken from ingots. Sand-cast test specimens would show somewhat lower values.

[b] The compression tests were made on machined test specimens (sand castings) of 1 sq. in. in sectional area and 1 in. in height. The compression deformation limit is taken as the load producing a compression in the specimen of 0.001 in. At the request of Committee B-2 on Non-Ferrous Metals and Alloys, Committee E-1 on Methods of Testing is giving consideration to revising the dimensions of compression test specimens and the method of determining the so-called "compression deformation limit." The revision of the values in this column, on the basis of cylindrical specimens 1 sq. in. in sectional area and 3 in. in height is contemplated. A revision of the methods of determining compression deformation limit is also under consideration.

Alloy	Examples of Use	Foundry Manipulation	Characteristics
No. 1	Commercial bronze for general service	Easily handled	Machines well
No. 2	High-pressure steam fittings	Easily handled	Machines well
No. 3	Steam fittings subjected to moderate pressure	Easily handled	Machines well
No. 4	High-grade red brass for general service	Easily handled	Machines well
No. 5	Reddish-yellow alloy for air, gas and water fittings	Not difficult	Machines easily
No. 6	Valve fittings for low pressure	Not difficult	Machines very easily
No. 7	Bearings for heavy pressure (may later be eliminated in favor of Alloy No. 9)	Not difficult	Machines easily
No. 8	Bearings for heavy pressure (lower cost than Alloy No. 7)	Not difficult	Machines easily
No. 9	General service bearings	Not difficult	Machines easily
No. 10	Bearings operated at high speed and under light or medium pressure	Not difficult	Machines easily
No. 11	Car journal bearings and similar service	Not difficult	Machines easily
No. 12	Yellowish red alloy for plumbers' fittings	Not difficult	Machines easily
No. 13	Yellow brass for light castings and ornamental work not requiring strength or subjected to internal pressure	Not difficult	Machines easily
No. 14	Yellow brass for heavier castings	Not difficult	Machines easily
No. 15	Plumbers' flanges, scupper pipes, etc	Very difficult. Aluminum up to 0.30 per cent improves casting properties, but increases shrinkage.	Hard to machine. Not suitable for bearings or water pressure fittings.

TENTATIVE SPECIFICATIONS
FOR
SEAMLESS COPPER TUBING, BRIGHT ANNEALED[1]

A.S.T.M. Designation: B 68 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1930.

Scope. 1. These specifications cover annealed copper tubing suitable for use in refrigerators, oil lines, gasoline lines, etc., where tubing absolutely free from scale and dirt is required.

MANUFACTURE

Process. 2. The tubing shall be made from copper that has been de-oxidized by means of phosphorus.

3. The tubing shall be bright annealed after the last drawing operation or after the coiling, if coiling is required.

4. The tubing shall be thoroughly recrystallized and have an average grain size not exceeding 0.040 mm. in diameter.

CHEMICAL PROPERTIES AND TESTS

Chemical Composition. 5. The material shall conform to the following requirements as to chemical composition:

Copper, minimum	99.90 per cent
Phosphorus, maximum	0.10 per cent

Sampling. 6. The sample for chemical analysis shall consist of drillings, millings or clippings, taken from each lot of 5000 lb. or fraction thereof, and shall be divided into three equal parts, each of which shall be placed in a sealed package, one for the seller, one for the purchaser, and one for an umpire, if necessary.

PHYSICAL PROPERTIES AND TESTS

Physical Properties. 7. (*a*) The material shall conform to the following minimum requirements as to tensile properties:

Tensile strength, lb. per sq. in.	30 000
Elongation in 2 in., per cent	40

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. D. K. Crampton, Secretary of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Chase Metal Works, Waterbury, Conn.

(*b*) Five test specimens shall be selected for physical test from each lot of 5000 lb. or fraction thereof.

PERMISSIBLE VARIATIONS IN DIMENSIONS

Dimensional Variations.

8. The mean inside and outside diameters and the wall thickness of the tubing shall not vary more than the following amounts from that specified:

Mean Inside and Outside Diameters, in.	Permissible Variations, in.
Up to 1, inclusive	±0.0025
Over 1 to 2, inclusive	±0.003

Wall Thickness Stubbs Gage No.	In.	Permissible Variations, in.
Under 14 to 17, inclusive	0.082 to 0.058, inclusive	±0.004
Under 17 to 20, inclusive	0.057 to 0.035, inclusive	±0.003
Under 20 to 23, inclusive	0.034 to 0.025, inclusive	±0.0025
Under 23	Under 0.025	±0.0025

No combination of variations on the same tube shall make the thickness of the wall vary from the nominal thickness by more than these amounts.

Lengths.

9. The lengths of the tubing, when measured at a temperature of 68° F. (20° C.) shall not vary from that specified on the purchase order by more than the following amounts:

For Straight Lengths

Ordered Length, ft.	Permissible Variations, in. Minus	 Plus
Up to 8, inclusive	0	$\frac{1}{16}$
Over 8 to 15, inclusive	0	$\frac{1}{8}$
Over 15 to 20, inclusive	0	$\frac{3}{16}$

For Coils

Ordered Length, ft.	Permissible Variations, in. Minus	 Plus
Up to 10	0	2
Over 10 to 20, inclusive	0	3
Over 20 to 40, inclusive	0	6
Over 40 to 80, inclusive	0	12
Over 80	0	24

WORKMANSHIP AND FINISH

Workmanship and Finish.

10. The finished tubing shall be smooth, free from interior and exterior mechanical imperfections, and shall have a clean, bright appearance.

PACKING AND MARKING

Packing.

11. The tubing shall be packed in such a manner as to prevent damage in ordinary handling and transportation.

Terms of Rejection. 12. All boxes, bundles, or barrels shall bear the following information: purchase order number, manufacturer's name, size and kind of material, and part number, if any.

REJECTION

Marking. 13. Material failing to comply with the above specifications may be rejected and returned for replacement or full credit at the option of the purchaser.

TENTATIVE METHOD OF TEST
FOR
THERMOELECTRIC POWER[1]

A.S.T.M. Designation: B 77 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. This method is intended for testing the thermoelectric power of a metal with respect to copper when the temperatures of the junctions lie between 0 and 100° C.

Purpose. 2. The purpose of this method is to determine the suitability of different metals for use in resistance apparatus in which a low thermoelectric power is desired. As most electric circuits are largely composed of copper, the thermoelectric power of a resistance metal will generally be measured against copper.

Definition. 3. *Thermoelectric Power.*—The thermoelectric power, Q, of one metal with respect to another is defined as the electromotive force in an electric circuit which consists of these two metals when the junctions between the two metals have a 1° C. difference in temperature.

NOTE.—Experimentally, it has been found that the thermoelectric power of two metals is not a constant but depends on the mean temperature of the junctions. However, over a range of temperature from 0 to 100° C. it is usually sufficient to assume that the thermoelectric power is independent of temperature, or that:

$$Q = \frac{E}{(t' - t)}$$

where E = the electromotive force developed in the circuit;
t' = the higher temperature in degrees Centigrade at one junction; and
t = the lower temperature in degrees Centigrade at the other junction.

TEST SPECIMEN

Test Specimen. 4. The metal to be tested shall be in the form of sheet, ribbon or wire and of such length that the two ends can readily be maintained at different temperatures. At each end of the specimen a copper lead of convenient size shall be fastened. These leads shall make good electrical contact with the specimen, such as that obtained by welding, brazing, or soldering. Slight impurities in the copper have a negligible effect on the thermoelectric power.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. F. E. Bash, Secretary of Committee B-4 on Electrical-Heating, Electrical-Resistance and Electric-Furnace Alloys, Technical Department, Driver-Harris Co., Harrison, N. J.

NOTE.—When necessary to specify the quality of the copper contacts reference should be made to the Standard Specifications for Soft or Annealed Copper Wire (A.S.T.M. Designation: B 3) of the American Society for Testing Materials.[1]

PROCEDURE

Measurement of Temperature.

5. As a matter of precaution, the temperatures used in determining the thermoelectric power should be approximately the same as that to which the material will be subjected in practice. The temperature at each of the two junctions shall be measured by a device which is sufficiently accurate to determine the temperature difference with an error not exceeding 5 per cent. A convenient method of determining the temperature of the junction is to immerse each junction in a beaker of oil which is maintained at the desired temperature. The beakers shall be supported by blocks of metal, sand baths or other means whose thermal capacity is such that when the supply of heat is cut off, their temperature will decrease at rates less than 0.2° C. per minute. To insure that the temperatures of the junctions shall not be influenced by heat conduction along the specimen, the distance in each beaker from the surface of the oil to the junction shall not be less than ten times the minimum cross-section dimension of the resistance material nor less than one hundred times the minimum cross-section dimension of the copper leads and in no case less than 2 in. The temperature of the oil in each beaker may be determined by a mercury thermometer graduated in Centigrade degrees, the range being 0 to 100° C.

Measurement of Electromotive Force.

6. The electromotive force shall be determined by a method which will give the value correct within 5 per cent. Three different methods of measuring the electromotive force are in common use, namely, (1) the potentiometer method in which the unknown electromotive force is compared with that of a standard cell; (2) the drop in potential method in which the unknown electromotive force is compared with the difference in potential between the terminals of a known resistance when a measured current flows through it; and (3) the galvanometer method in which the electromotive force is measured by the deflection of a suitable galvanometer. In any case, precautions shall be taken to insure that there are no parasitic electromotive forces in the measuring circuit, a condition which may be

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 629.

determined by placing both junctions in the same beaker, in which case no appreciable electromotive force shall be indicated.

Polarity of the Metal.

7. The metal or alloy tested shall be considered to have positive polarity when, in a circuit consisting of copper and the metal or alloy, the direction of current flow in the metal or alloy is from the higher to the lower temperature junction.

REPORT

Report.

8. The report shall include the following:

(*a*) The character of the metal tested;
(*b*) The size, shape, and length of specimen;
(*c*) The temperature at each junction in degrees Centigrade;
(*d*) The type of apparatus used in measuring the electromotive force;
(*e*) The observed electromotive force;
(*f*) The thermoelectric power; and
(*g*) The polarity of the metal tested.

TENTATIVE SPECIFICATIONS
FOR
HIGH-EARLY-STRENGTH PORTLAND CEMENT[1]

A.S.T.M. Designation: C 74 - 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Definition.

1. High-early-strength portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination excepting water and calcined or uncalcined gypsum.

CHEMICAL PROPERTIES

Chemical Limits.

2. The following limits shall not be exceeded:

Loss on ignition, per cent	4.00
Insoluble residue, per cent	0.85
Sulfuric anhydride (SO_3), per cent	2.50
Magnesia (MgO), per cent	5.00

PHYSICAL PROPERTIES

Fineness.

3. The residue on a standard No. 200 sieve shall not exceed 22 per cent by weight.

Soundness.

4. A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting.

5. The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength.

6. The average tensile strength in pounds per square inch of not less than three standard mortar briquets (see Section 47) composed of one part of cement and three parts of standard sand, by weight, shall be equal to or higher than the following:

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. F. H. Jackson, Secretary of Committee C-1 on Cement, U. S. Bureau of Public Roads, Washington, D. C.

Age at Test, days	Storage of Briquets	Tensile Strength lb. per sq. in.
1	1 day in moist air	275
3	1 day in moist air, 2 days in water	375

7. If, at the option of the purchaser, a 28-day test (with storage of 1 day in moist air and 27 days in water) is required, the average tensile strength obtained at 28 days shall be higher than the strength obtained at 3 days.

PACKING, MARKING AND STORAGE

Packages and Marking.

8. The cement shall be delivered in packages as specified with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. When shipped in bulk, this information shall be contained in the shipping advices accompanying the shipment. A bag shall contain 94 lb. net. A barrel shall contain 376 lb. net. All packages shall be in good condition at the time of inspection.

Storage.

9. The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

INSPECTION AND REJECTION

Inspection.

10. Every facility shall be provided the purchaser for careful sampling and inspection at either the mill or at the site of the work, as may be specified by the purchaser. At least 6 days from the time of sampling shall be allowed for the completion of the 1-day tests, 8 days for the 3-day tests, and at least 33 days shall be allowed for the completion of the 28-day tests. The cement shall be tested in accordance with the methods hereinafter prescribed.

Rejection.

11. The cement may be rejected if it fails to meet any of the requirements of these specifications.

12. Cement remaining in storage prior to shipment for a period greater than 6 months after test shall be retested and shall be rejected if it fails to meet any of the requirements of these specifications.

13. Cement shall not be rejected on account of failure to meet the fineness requirement if upon retest after drying at 100° C. for one hour it meets this requirement.

14. Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter. The provisional acceptance of the cement at the mill shall not deprive the purchaser of the right of rejection on a retest of soundness and time of setting at the time of delivery of cement to the purchaser.

15. Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

METHODS OF TESTING

Methods of Testing.

16. The cement shall be sampled and tested in accordance with the Standard Methods of Testing Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials[1] except that in Section 11 the sulfuric anhydride content shall be reported as 2.50 per cent when all results are in excess of the specified limit but within the permissible variation of 0.10 per cent.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 30.

TENTATIVE SPECIFICATIONS
FOR
GYPSUM SHEATHING BOARD[1]

A.S.T.M. Designation: C 79 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Definition. 1. Gypsum sheathing boards are sheets or slabs having an incombustible core of gypsum, and designed to be used as a sheathing in the frame of buildings.

MANUFACTURE

Composition. 2. Gypsum sheathing board shall consist of an incombustible core of gypsum, with or without fiber, surfaced with paper or other fibrous material firmly bonded to the core.

PROPERTIES AND TESTS

Flexural Strength. 3. Flexural strength test specimens shall be 12 in. (300 mm.) in width and approximately 16 in. (410 mm.) in length. When tested in accordance with the methods described in Section 13, specimens taken from the gypsum sheathing boards shall carry not less than the following loads without showing a breaking of the bond between the surfacing and the core:

Thickness, in.	Thickness, mm.	Load, lb. Knife Edges Across Fiber of Surfacing	Load, lb. Knife Edges Parallel to Fiber of Surfacing
½	12.7	100	40
¾	19.0	125	55

Sampling. 4. At least 1 per cent of the number of gypsum sheathing boards in a shipment, but not less than ten boards, shall be so selected as to be representative of the shipment. Twenty-five per cent of such selected boards, but not less than ten individual boards, shall constitute a sample for purposes of test. When a shipment consists of more than one car or carrier load, a sample shall be selected from each car or carrier.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. H. J. Schweim, Secretary of Committee C-11 on Gypsum, Gypsum Assn., 211 W. Wacker Drive, Chicago, Ill.

DIMENSIONS, WEIGHTS AND PERMISSIBLE VARIATIONS

Thickness.

5. Gypsum sheathing boards shall be either $\frac{1}{2}$ in. (12.7 mm.), or $\frac{3}{4}$ in. (19 mm.), in thickness, except that average thicknesses varying not more than $\frac{1}{16}$ in. (1.6 mm.) from the nominal thickness, and local variations of $\frac{1}{16}$ in. (1.6 mm.) in the thickness of the individual boards will be permissible.

Width and Length.

6. The nominal width of gypsum sheathing boards shall be either 24 in. (610 mm.), or 32 in. (810 mm.) and the nominal length either 6 ft. 8 in. (2.03 meters) or 8 ft. (2.44 meters). A variation of $\frac{1}{8}$ in. (3.2 mm.) under or over the specified width, and of $\frac{1}{4}$ in. (6.3 mm.) under or over the specified length will be permissible.

Weight.

7. The weight of gypsum sheathing board per 1000 sq. ft. shall conform to the following requirements:

Thickness,		Weight, Minimum		Weight, Maximum	
in.	mm.	lb.	kg.	lb.	kg.
$\frac{1}{2}$	12.7	2000	907	3000	1361
$\frac{3}{4}$	19.0	3000	1361	4000	1814

FINISH

Finish.

8. The edges and ends shall be straight and solid. A variation of $\frac{1}{8}$ in. (3.2 mm.) from parallelism of opposite edges is permissible. Gypsum sheathing board shall be free from cracks and imperfections that will render them unfit for use.

PACKING AND MARKING

Packing and Marking.

9. Shipments of gypsum sheathing board shall conform to the following requirements:

(*a*) They shall be shipped so as to be kept dry and free from moisture.

(*b*) When shipped for resale, the following information shall be shown upon each board:

Name of manufacturer;
Brand;
Nominal thickness.

INSPECTION AND REJECTION

Inspection.

10. Inspection may be made either at the point of shipment or at the point of delivery. The inspector representing the purchaser shall have free access to the carriers being loaded for shipment to the purchaser. He shall be afforded all reasonable facilities for inspection and sampling, which shall be so conducted as not to interfere unnecessarily with the loading of the carriers.

Rejection.

11. Any rejection shall be based upon failure to conform to the requirements of these specifications; and shall be reported within ten working days from the receipt of the shipment by the consignee. The notice of rejection shall contain a specific statement of the respects in which the boards have failed to conform to the requirements of these specifications.

Rehearing.

12. Claims for rehearing shall be valid only if made within 20 working days from the receipt of notice of specific cause for rejection.

METHOD OF TESTING

Method of Testing.

13. (*a*) Test specimens for the flexural strength test shall be taken from not less than ten gypsum boards.

(*b*) The test specimens shall be 12 in. (300 mm.) in width and approximately 16 in. (410 mm.) in length. They shall be supported on fixed parallel bearings spaced 14 in. (350 mm.) on centers, and shall be loaded through a similar bearing midway between the supports. All bearing and load surfaces shall be true, shall engage the full width of the test specimen, and shall be rounded to a radius of $\frac{1}{8}$ in. (3.2 mm.).

(*c*) Test loads shall be applied at a uniform rate of 60 lb. (27.22 kg.) per minute with a permissible variation of ±10 per cent in the rate. Flexure test results shall be reported when the load is applied across the fiber of the surfacing and also parallel to the fiber of the surfacing.

TENTATIVE SPECIFICATIONS
FOR
CONCRETE AGGREGATES[1]

A.S.T.M. Designation: C 33 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1923, 1926, 1928, 1930.[2]

QUALITY OF AGGREGATES

It is recognized that for certain purposes satisfactory results may be obtained with materials not conforming to these specifications. In such cases the use of fine and coarse aggregates not conforming to these specifications should be authorized only under special provisions based upon laboratory studies of the possibility of designing a mixture of materials to be used on the job that will yield concrete equivalent to the specified mixture made with material complying with these specifications in all respects.

FINE AGGREGATE

General Characteristics. 1. Fine aggregate shall consist of sand or other approved inert materials with similar characteristics, or a combination thereof, having hard, strong, durable particles and shall conform to the requirements of these specifications.

Deleterious Substances. 2. (*a*) The amount of deleterious substances shall not exceed the following maximum requirements:

	PER CENT BY WEIGHT
Removed by decantation	3
Coal	1
Clay lumps	1
Other local deleterious substances (such as shale, alkali, mica, coated grains, soft and flaky particles)	....
Total coal, clay lumps, shale, soft fragments and other local deleterious substances	5

NOTE.—It is recognized that under certain conditions percentages of deleterious substances less than those shown in the table should be specified as a maximum.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 545 Munsey Building, Washington, D. C.

[2] Latest revision approved by Committee E-10 on Standards, September 18, 1930.

(*b*) All fine aggregate shall be free from injurious amounts of organic impurities. Aggregates subjected to the colorimetric test for organic impurities and producing a color darker than the standard shall be rejected unless they pass the mortar strength test as specified in Section 4.

Grading.

3. (*a*) Fine aggregate shall be well graded from coarse to fine and when tested by means of laboratory sieves[1] shall conform to the following requirements:

	PER CENT
Passing a $\frac{3}{8}$-in. sieve	100
Passing a No. 4 sieve	(85) to (100)
Passing a No. 16 sieve	(45) to (80)
Passing a No. 50 sieve	(2) to (30)
Passing a No. 100 sieve	(0) to (5)

NOTE.—Figures in parentheses are suggested as limiting percentages but they may be altered within these limits to suit local conditions.

(*b*) In case the concrete resulting from a mixture of aggregates approaching the extreme limits for gradation is not of a workable character, or when finished does not exhibit a proper surface, due to an excess of particles approximately $\frac{1}{8}$ to $\frac{1}{2}$ in. in size, either a fine aggregate having a sufficiently greater percentage of fine material, or a coarse aggregate having a sufficiently smaller percentage of fine material must be used.

Mortar Strength.

4. Fine aggregates, when subjected to the mortar strength test, shall have a tensile or compressive strength at the age of 7 and 28 days of not less than (100) per cent of that developed by mortar of the same proportions and consistency made of the same cement and standard Ottawa sand.

NOTE.—Percentage in parentheses is recommended but it may be altered to suit local conditions.

COARSE AGGREGATE

General Characteristics.

5. Coarse aggregate shall consist of crushed stone, gravel, blast-furnace slag, or other approved inert materials of similar characteristics, or combinations thereof, having hard, strong, durable pieces, free from adherent coatings and conforming to the requirements of these specifications.

Deleterious Substances.

6. The amount of deleterious substances shall not exceed the following maximum requirements:

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[1] For detail requirements for these sieves, see the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, 1930 Book of A.S.T.M. Standards, Part II, p. 1119.

	PER CENT BY WEIGHT
Removed by decantation	1
Shale	1
Coal	1
Clay lumps	0.5
Soft fragments	5
Other local deleterious substances (such as alkali, friable, thin, elongated, or laminated pieces)	....
Total shale, coal, clay lumps and soft fragments	5

NOTE.—It is recognized that under certain conditions percentages of deleterious substances less than those shown in the table should be specified as a maximum.

Grading. 7. (*a*) Coarse aggregate shall be well graded, between the limits specified, and shall conform to the following requirements:

		PER CENT BY WEIGHT
Passing .... in. Sieve[1] or Screen (maximum size)		not less than (95)
Passing .... in. Sieve[1] or Screen	(intermediate size)	not less than (40)
	(one-half maximum size)	not more than (75)
Passing .... in. Sieve[1] or Screen	(intermediate sizes)	not less than ....
	(as needed)	not more than ....
Passing No. 4 Sieve or a $\frac{1}{4}$-in. Screen		not more than (10)

NOTE.—Where a range is shown the engineer should use an appropriate figure within the limits recommended. The percentages in parentheses are recommended but may be altered to suit local conditions.

(*b*) In case the concrete resulting from a mixture of aggregates approaching the extreme limits for gradation is not of a workable character, or when finished does not exhibit a proper surface, due to an excess of particles approximately $\frac{1}{8}$ to $\frac{1}{2}$ in. in size, either a fine aggregate having a sufficiently greater percentage of fine material, or a coarse aggregate having a sufficiently smaller percentage of fine material shall be used.

Weight of Slag. 8. Blast-furnace slag that meets the grading requirements of these specifications shall conform to the following minimum weight requirements:

Base concrete	65 lb. per cu. ft.
Surface concrete (subject to abrasion)	70 lb. per cu. ft.

Durability. 9. Coarse aggregate shall pass a sodium sulfate accelerated soundness test, except that aggregates failing in the accelerated soundness test may be used if they pass a satisfactory freezing and thawing test.

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[1] The question whether round or square openings shall be used for testing aggregates is now being studied by the Section on Coarse Screens of the Technical Committee on Size and Shape of Committee E-1 on Methods of Testing.

NOTE.—Many engineers believe that an abrasion test for coarse aggregate to be used in concrete subject to abrasion is important, but no test limits are specified, due to the status of knowledge concerning suitable specification limits for this test. The Committee believes that the abrasion tests when applied to blast-furnace slag do not meet the requirements for a desirable test.

METHODS OF SAMPLING AND TESTING

Methods of Testing.

10. The properties enumerated in these specifications shall be determined in accordance with the following methods of test of the American Society for Testing Materials, except as specified in Paragraph (*e*).

(*a*) *Sampling.*—Standard Methods of Sampling Stone, Slag, Gravel, Sand and Stone Block for Use as Highway Materials, Including Some Material Survey Methods (A.S.T.M. Designation: D 75).[1]

(*b*) *Sieve Analysis.*—Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C 41).[2]

(*c*) *Decantation Test.*—Standard Method of Decantation Test for Sand and Other Fine Aggregates (A.S.T.M. Designation: D 136).[3]

(*d*) *Organic Impurities.*—Standard Method of Test for Organic Impurities in Sands for Concrete (A.S.T.M. Designation: C 40).[4]

(*e*) *Mortar Strength.*—Methods of Making Compression and Tension Tests of Fine Aggregate for Concrete as adopted by the American Association of State Highway Officials.

(*f*) *Compressive Strength.*—Standard Methods of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39).[5]

(*g*) *Soundness.*—Proposed Method of Test for Soundness of Coarse Aggregate (Sodium Sulfate Soundness Test),[6] as adopted by the American Association of State Highway Officials.

(*h*) *Freezing and Thawing.*—Method of Freezing and Thawing Tests of Drain Tile as described in the Standard Specifications for Drain Tile (A.S.T.M. Designation: C 4).[7]

(*i*) *Shale and Coal.*—Proposed Method of Test for Percentage of Shale in Aggregate,[8] as adopted by the American Association of State Highway Officials.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 622.

[2] *Ibid.*, p. 155.

[3] *Ibid.*, p. 618.

[4] *Ibid.*, p. 154.

[5] *Ibid.*, p. 143.

[6] Appendix II, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 361 (1928).

[7] 1930 Book of A.S.T.M. Standards, Part II, p. 249.

[8] Appendix III, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 362 (1928).

(*j*) *Soft Fragments.*—Proposed Method of Test for Quantity of Soft Pebbles in Gravel,[1] as adopted by the American Association of State Highway Officials.

(*k*) *Coal and Lignite.*—Proposed Method of Test for Determination of Coal and Lignite in Sand,[2] as adopted by the American Association of State Highway Officials.

(*l*) *Moisture.*—Standard Method of Test for Surface Moisture in Fine Aggregate (A.S.T.M. Designation: C 70).[3]

(*m*) *Consistency.*—Tentative Method of Test for Consistency of Portland-Cement Concrete (A.S.T.M. Designation: D 138 – 26 T).[4]

(*n*) *Weight of Slag.*—Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[5]

(*o*) *Abrasion.*—If abrasion tests are made the following methods of test are recommended:

(1) *Abrasion of Gravel.*—Tentative Method of Test for Abrasion of Gravel (A.S.T.M. Designation: D 289 – 28 T).[6]

(2) *Abrasion of Rock.*—Standard Method of Test for Abrasion of Rock (A.S.T.M. Designation: D 2),[7] except that for specific gravities lower than 2.2 a 4000-g. sample shall be used.

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[1] Appendix IV, 1928 Report of Committee C-9 on Concrete and Concrete Aggregates, see *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 363 (1928).

[2] Appendix V, *Ibid.*, p. 365.

[3] 1930 Book of A.S.T.M. Standards, Part II, p. 162.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 874 (1926); also 1930 Book of A.S.T.M. Tentative Standards, p. 446.

[5] 1930 Book of A.S.T.M. Standards, Part II, p. 151.

[6] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 940 (1928); also 1930 Book of A.S.T.M. Tentative Standards, p. 443.

[7] 1930 Book of A.S.T.M. Standards, Part II, p. 609.

TENTATIVE LABORATORY METHOD

OF

MAKING FLEXURE TESTS OF CONCRETE, USING A SIMPLE BEAM WITH CENTER LOADING[1]

A.S.T.M. Designation: C 78 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope.

1. These methods are intended to cover the making of flexure tests of concrete in the laboratory where accurate control of quantities of materials and test conditions is possible. They are intended to apply to hand-mixed concrete with slight modification from that used in making compression test specimens, described in the Standard Methods of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39) of the American Society for Testing Materials.[2]

Preparation of Materials.

2. Materials shall be brought to room temperature (18 to 24° C., 65 to 76° F.), before beginning the tests. Cement shall be stored in a dry place; preferably in covered metal cans. The cement shall be thoroughly mixed in advance, in order that the sample may be uniform throughout the tests. It shall be sieved through a No. 16 (1190-micron) sieve and all lumps rejected. Aggregates shall be in a room-dry condition when used in concrete tests. In general, coarse aggregates should be separated on the No. 4 (4760-micron), $\frac{3}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{2}$, 2, $2\frac{1}{2}$ and 3-in. sieves and recombined to the average original sieve analysis for each batch. Fine aggregate should be separated into different sizes also, in cases where unusual gradings are being studied.

Sampling for Preliminary Tests.

3. Representative samples of all concrete materials shall be secured for preliminary tests prior to the proportioning and mixing of the concrete. Test samples of cement may be made up of a small quantity from each sack used in the concrete tests. Test samples of aggregates may be taken from larger lots by quartering.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, 545 Munsey Building, Washington, D. C.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 143.

Cement Tests.

4. Cement shall be tested in accordance with the Standard Methods of Testing Cement (A.S.T.M. Designation: C 77) of the American Society for Testing Materials.[1]

Fine Aggregate Tests.

5. Fine aggregates (passing through a No. 4 (4760-micron) sieve shall be subjected, when specified, to the following tests of the American Society for Testing Materials:

(*a*) *Sieve Analysis.*—Sieve analysis tests made in accordance with the Standard Method of Test for Sieve Analysis of Aggregates for Concrete (A.S.T.M. Designation: C 41).[2]

(*b*) *Organic Impurities.*— Test for organic impurities made in accordance with the Standard Method of Test for Organic Impurities in Sands for Concrete (A.S.T.M. Designation: C 40).[3]

(*c*) *Decantation Test.*—Test for quantity of silt, clay and dust made in accordance with the Standard Method of Decantation Test for Sand and Other Fine Aggregates (A.S.T.M. Designation: D 136).[4]

(*d*) *Unit Weight.*—Test for unit weight made in accordance with the Standard Method of Test for Unit Weight of Aggregate for Concrete (A.S.T.M. Designation: C 29).[5]

(*e*) *Tensile Strength.*—Strength test of 1:3 mortar by weight at 7 and 28 days in comparison with standard sand mortar in accordance with the Standard Methods of Testing Cement (A.S.T.M. Designation: C 77).[1]

Coarse Aggregate Tests.

6. Coarse aggregates (retained on a No. 4 (4760-micron) sieve) shall be subjected when required to the following tests:

(*a*) *Sieve Analysis.*—Sieve analysis test as specified in Section 5 (*a*).

(*b*) *Decantation Test.*—Tests for quantity of silt, clay and dust made in accordance with Standard Method of Test for Quantity of Clay and Silt in Gravel for Highway Construction (A.S.T.M. Designation: D 72) of the American Society for Testing Materials.[6]

Unit Weight of Mixed Aggregates.

7. The unit weight of mixed fine and coarse aggregates as used in the concrete tests shall be determined in accordance with the method specified in Section 5 (*d*).

Proportions.

8. The quantities of each size of aggregate to be used in each batch shall be determined on the basis of the sieve analyses of the fine and coarse aggregates and the unit weight of the mixed aggregates. The exact quantities of cement and of each size of aggregate for each batch shall be determined by weight. The quantity of water for each batch shall be accurately measured. The quantities of mate-

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 30.

[2] *Ibid.*, p. 155.

[3] *Ibid.*, p. 154.

[4] *Ibid.*, p. 618.

[5] *Ibid.*, p. 151.

[6] *Ibid.*, p. 620.

rials may be expressed as (*a*) 1 volume of cement to .... volumes of total aggregate mixed as used, or (*b*) 1 volume of cement to .... volumes of fine aggregate, and .... volumes of coarse aggregate, or (*c*) 1 part by weight of cement, ... parts by weight of fine aggregate, and .... parts by weight of coarse aggregate.

Size and Shape of Specimens.

9. (*a*) The following minimum cross-sections shall be used for the flexure test specimens:

SIZE OF COARSE AGGREGATE	WIDTH	DEPTH
$1\frac{1}{2}$ in.	6 in.	6 in.
2 and $2\frac{1}{2}$ in.	8 in.	8 in.

(*b*) The span of the test specimen shall be three times the designed depth.

Mixing Concrete.

10. Concrete shall be mixed by hand in batches of such size as to leave a small quantity of concrete after molding a single test specimen or a series of identical test specimens to be tested at different ages. The batch shall preferably be mixed in a water-tight, shallow, galvanized pan with a shovel as follows:

(*1*) The cement and fine aggregate shall be mixed dry until the mixture is homogeneous in color.

(*2*) The coarse aggregate shall be added and mixed dry.

(*3*) Sufficient water shall be added to produce concrete of the desired consistency.

(*4*) The mass shall be mixed thoroughly for at least 3 minutes or until the resulting concrete is homogeneous in appearance.

Consistency.

11. The consistency of each batch of concrete shall be measured by the slump test made in accordance with the Tentative Method of Test for Consistency of Portland Cement Concrete for Pavements or for Pavement Base (A.S.T.M. Designation: D 138 – 26 T) of the American Society for Testing Materials.[1]

Forms.

12. (*a*) The forms and base shall be rigid, water-tight and nonabsorptive. The forms shall be well braced and also tightly joined together to prevent slipping.

(*b*) The inside faces of the form shall be oiled with a heavy paraffin base oil or a thin coating of paraffin shall be applied.

Molding Test Specimens.

13. Concrete shall be placed in two equal layers for specimens not exceeding 6 by 6 in. in cross-section. Each layer shall be rodded 50 times for each square foot of area. The top layer shall be such that the beam form is slightly heaped up with concrete. After the rodding is completed for each layer, the specimen shall be spaded

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 874 (1926); also 1930 Book of A.S.T.M. Tentative Standards, p. 446.

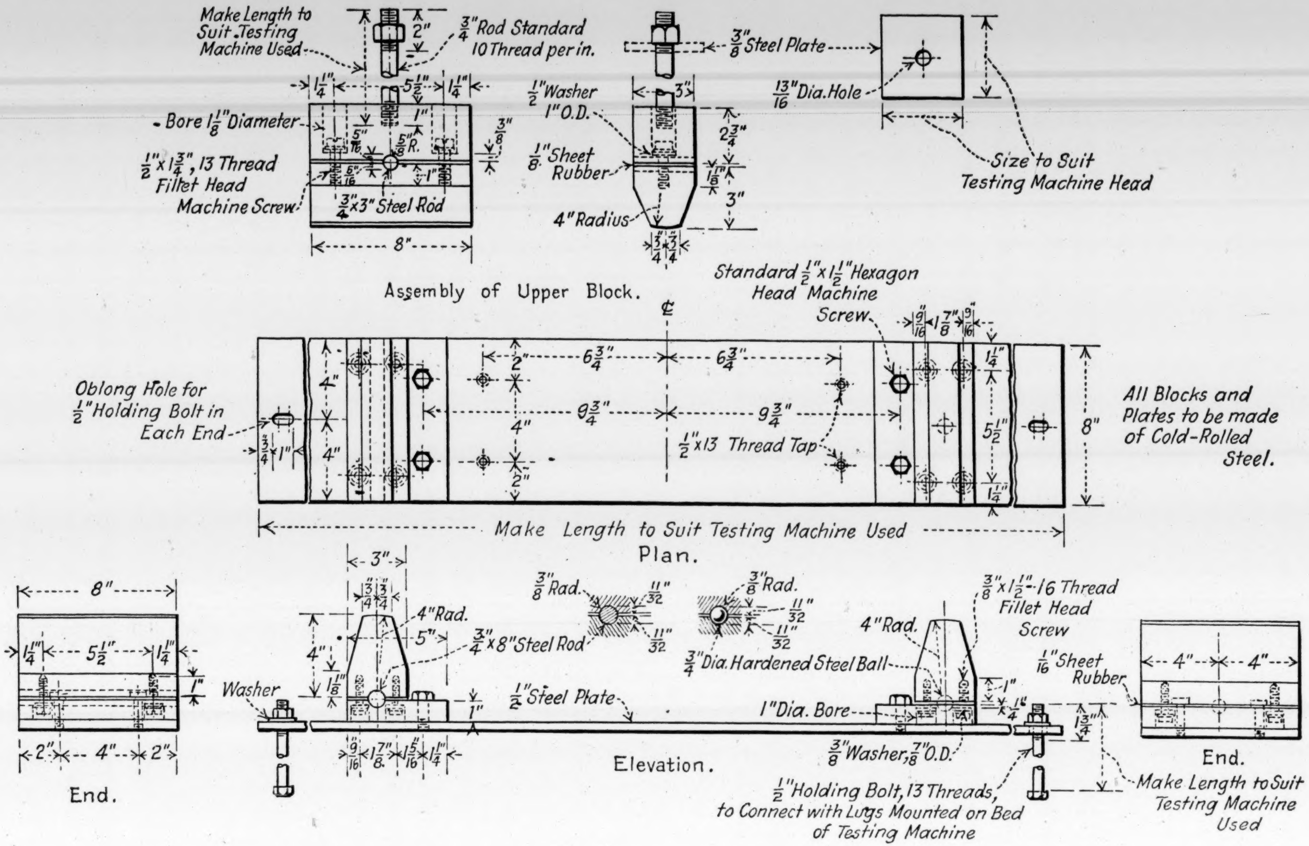
Make Length to Suit Testing Machine Used
2"
3/4" Rod Standard 10 Thread per in.
1 1/4"
5 1/2"
1 1/4"
Bore 1 1/8" Diameter
1"
5/16"
5/8" R.
3/8"
1/2" x 1 3/4", 13 Thread Fillet Head Machine Screw
5/16"
1"
3/4" x 3" Steel Rod
8"
1/2" Washer 1" O.D.
1/8" Sheet Rubber
4" Radius
3"
2 3/4"
1/8"
3"
3/4
3/4
3/8" Steel Plate
13/16" Dia. Hole
Size to Suit Testing Machine Head
Assembly of Upper Block.
Standard 1/2" x 1 1/2" Hexagon Head Machine Screw
9/16"
1 7/8"
9/16"
Oblong Hole for 1/2" Holding Bolt in Each End
3/4
1"
4"
4"
2"
6 3/4"
6 3/4"
9 3/4"
9 3/4"
4"
2"
1/2" x 13 Thread Tap
1 1/4"
5 1/2"
1 1/4"
8"
All Blocks and Plates to be made of Cold-Rolled Steel.
Make Length to Suit Testing Machine Used
Plan.
8"
1 1/4"
5 1/2"
1 1/4"
1"
2"
4"
2"
End.
3"
3/4
3/4
4" Rad.
4"
5"
1 1/8"
3/4" x 8" Steel Rod
Washer
1"
9/16
1 7/8"
1 5/16"
1 1/4"
3/8" Rad.
11/32"
11/32"
3/8" Rad.
11/32"
11/32"
3/4" Dia. Hardened Steel Ball
1/2" Steel Plate
Elevation.
4" Rad.
3/8" x 1 1/2"-16 Thread Fillet Head Screw
1/16" Sheet Rubber
1"
1/4"
1 3/4"
1" Dia. Bore
3/8" Washer, 7/8" O.D.
1/2" Holding Bolt, 13 Threads, to Connect with Lugs Mounted on Bed of Testing Machine
4"
4"
End.
Make Length to Suit Testing Machine Used

FIG. 1.—Details of Design of Apparatus for Flexure Tests of Concrete.

along the sides and ends with a mason's trowel or other suitable spading tool. When the rodding and spading operation is completed, the top shall be struck off with a straight edge and finished with a cork float. The specimen should be made as quickly as possible and immediately covered over with a double layer of damp burlap.

Curing Test Specimens.

14. Concrete test specimens shall be removed from the forms, except the bottom section, 20 to 24 hours after molding, marked, weighed and then stored in damp sand, under damp cloths, or in a moist chamber until the date of test. The temperature of the curing room shall not fall outside the range of 60 to 75° F.

Number of Specimens.

15. The number of specimens to be tested shall be three or more made on different days.

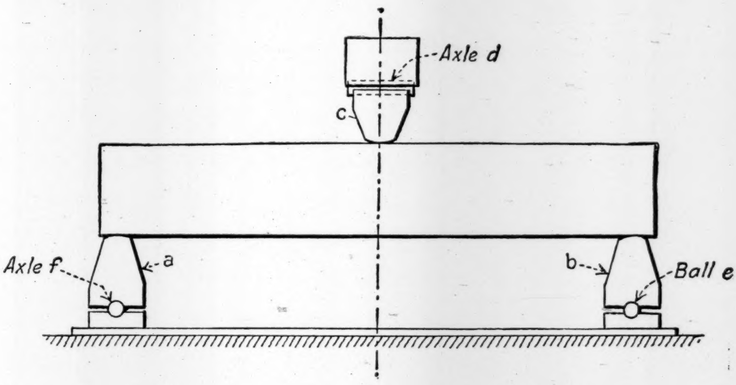

FIG. 2.—Diagramatic View of Set-up for Flexure Test.

Measurement of Specimens.

16. Measurements shall be made of the average width and average depth at the section of failure to the nearest 0.01 in.

Type of Transverse Testing Machine.

17. The center loading method shall be used in making flexure tests of concrete employing bearing blocks which will insure that forces applied to the beam will be vertical only and applied without eccentricity. A design of an apparatus which accomplishes this purpose is shown in Fig. 1.

Application of Load.

18. The specimen with the molded top up, shall be carefully centered on the transverse blocks and the load-applying block brought in contact with the upper surface of the beam. A diagrammatic view of the set-up is shown in Fig. 2. Then load may be applied rapidly up to approximately 50 per cent of the breaking load, after which it should be applied at a rate that the extreme fibers are stressed 150 lb. per sq. in. or less per minute.

Record of Test.

19. The report shall include the following:
   - (*a*) Results of the following tests of aggregates:
     - The weight per cubic foot,
     - Mechanical analysis,
     - The percentage of silt, loam, clay, etc.,
     - The specific gravity,
     - Nature of the aggregate:
       - (*1*) Composition (kind of minerals of which it is composed)
       - (*2*) Gravel, crushed stone, slag
       - (*3*) Source of supply
       - (*4*) Any additional information.
   - (*b*) Complete data on the acceptance tests of the portland cement.
   - (*c*) The proportions of each batch including the quantities of water, cement, fine and coarse aggregates used together with the weight per cubic foot and the yield.
   - (*d*) The consistency or slump of each batch.
   - (*e*) The weight and size of the beam including the weight when made, the weight when tested and the measurements at time of test.
   - (*f*) The curing conditions.
   - (*g*) The kind of machine used in testing, condition of end supports and the span length.
   - (*h*) The breaking load, type of failure and its exact location.
   - (*i*) The rate of application of the load.
   - (*j*) The age at test.

TENTATIVE METHODS OF TESTING BRICK[1]
(COMPRESSION, FLEXURE AND ABSORPTION)

A.S.T.M. Designation: C 67 – 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927: REVISED, 1928, 1930.

Scope.

1. These methods cover the following tests for brick:

The compression test;
The flexure or cross-bending test;
The absorption test.

COMPRESSION TEST

APPARATUS

Apparatus.

2. Any form of standard testing machine may be used for the compression test together with a spherical bearing block large enough entirely to cover the specimen.

TEST SPECIMEN

Test Specimen.

3. The test specimen shall consist of a half-brick. Any method which will produce a specimen with approximately plane and parallel ends, without shattering the specimen, may be used.

NOTE.—This permits the use of a suitable half-brick from the flexure test.

Preparation of Test Specimen.

4. A half-brick to be used for the compression test shall be prepared as follows: The two surfaces intended to receive the load from the testing machine shall receive a thin coating of shellac and be allowed to dry thoroughly. One of the shellaced bearing surfaces shall then receive a thin coat of a neat mortar of calcined gypsum (plaster of Paris). This mortared face of the specimen shall then be pressed on plate glass or a machined metal plate, previously oiled or covered with waxed paper, and the bedding material allowed to harden. This procedure shall be repeated with the other shellaced surface. Care shall be taken that the opposite faces so coated with bedding material shall be parallel. Depressions of recessed or panelled bricks shall be filled with neat portland-cement mortar which shall stand at least 24 hours before testing.

Number of Tests.

5. Compression tests shall be made on at least five half-brick test specimens from different bricks.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. W. McBurney, Secretary of Committee C-3 on Brick, U. S. Bureau of Standards, Washington, D. C.

PROCEDURE

Procedure. 6. (*a*) The half-brick test specimen shall be tested, placed flat.

(*b*) The bearing block shall be used on top of the test specimen in vertical testing machines. The center of the sphere of the bearing block shall be used in contact with the top bearing surface of the specimen, and in the vertical axis of the specimen. (Fig. 1.) The spherical bearing block shall be kept thoroughly lubricated to insure accurate adjustment, which should be made by hand under a small initial load.

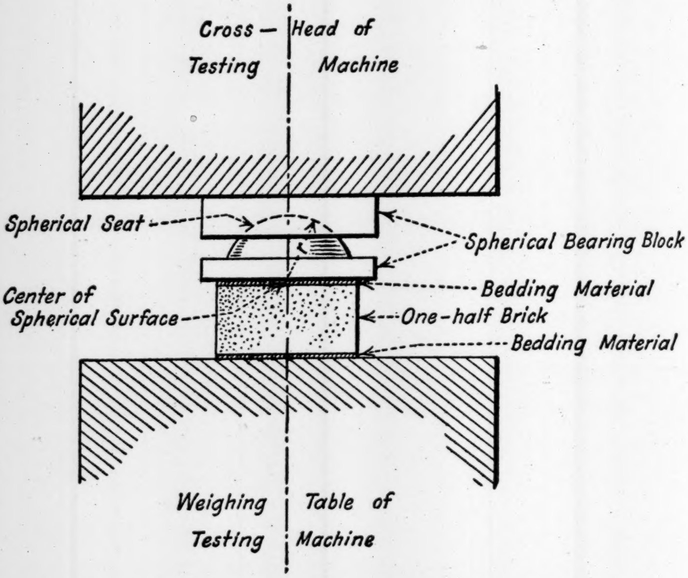
Cross — Head of
Testing Machine
Spherical Seat
Spherical Bearing Block
Center of Spherical Surface
Bedding Material
One-half Brick
Bedding Material
Weighing Table of
Testing Machine

FIG. 1.—Special Bearing Block for Use in Testing Brick.

(*c*) The speed of the moving head of the testing machine, during the application of the load, shall not be more than 0.05 in. per minute.

(*d*) During the test the beam of the testing machine shall be kept constantly in a floating position.

Compressive Strength. 7. The compressive strength in pounds per square inch shall be reported as the total maximum load, W, in pounds, indicated by the testing machine, divided by the average of the gross areas of the top and bottom of the specimen, A, in square inches, of the section of the specimen perpendicular to the line of application of the load.

The compressive strength in pounds per square inch shall be calculated from the formula:

$$\text{Compressive strength} = \frac{W}{A}$$

FLEXURE TEST

APPARATUS

8. (*a*) Any form of standard testing machine with knife edges as described in Paragraph (*b*) may be used for the flexure test. **Apparatus.**

NOTE.—Portable apparatus properly calibrated may be used.

(*b*) Knife edges shall be straight and have full contact with the specimen or bearing plate and they shall have a length at least equal to the width of the brick to be tested. Their bases shall be so curved or rounded as to permit free movement of the working edges, both longitudinally and transversely. The use of knife edges of the type shown in Fig. 2 is recommended, although other types may be used which will provide free movement and at the same time insure full and even bearing at all times during the test.

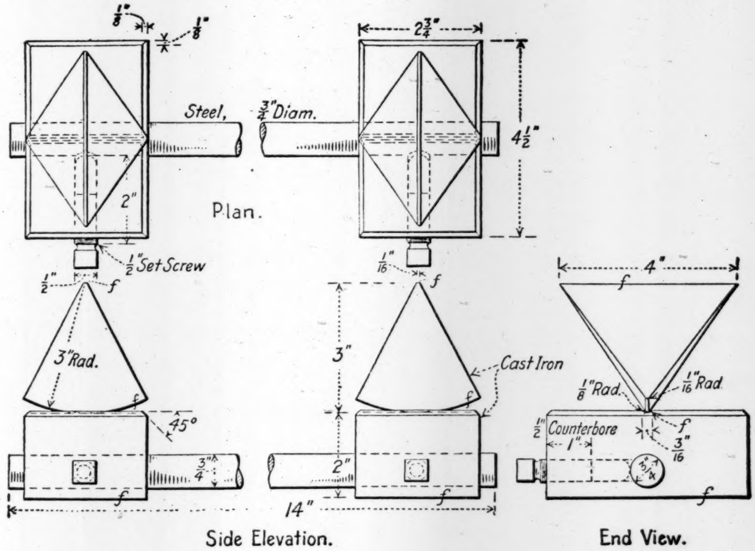
1/8"
1/8"
Steel, 3/4" Diam.
2 3/4"
4 1/2"
2"
Plan.
1/2" Set Screw
1/2"
f
1/16"
f
4"
f
3" Rad.
3"
Cast Iron
1/8" Rad.
1/16" Rad.
f
45°
1/2" Counterbore
1"
f
3/16"
3/4"
3/4"
2"
f
14"
f
f
Side Elevation.
End View.

FIG. 2.

TEST SPECIMEN

9. The test specimen shall be a whole brick. **Test Specimen.**

10. Flexure tests shall be made on at least five whole bricks. **Number of Tests.**

PROCEDURE

11. (*a*) A test specimen brick shall be placed flat-wise on the knife edges with a span of 7 in. and the load applied at mid-span. **Procedure.**

(*b*) A steel bearing piece ¼ in. in thickness, 1½ in. in width and of a length equal to the full width of the specimen shall be placed between the upper knife edge and the specimen.

(*c*) The speed of travel of the head of the testing machine, during the application of the load, shall not be more than 0.05 in. per minute.

Modulus of Rupture.

12. The modulus of rupture, R, in pounds per square inch shall be reported as calculated from the following formula:

$$R = \frac{3Wl}{2bd^2}$$

where W = the total load in pounds at which the brick failed;
l = the distance between the supports in inches;
b = the width of the brick in inches; and
d = the depth of the brick in inches.

ABSORPTION TEST

TEST SPECIMEN

Test Specimen.

13. The test specimen shall be a whole brick.

Number of Tests.

14. The absorption test shall be made on at least five whole bricks.

PROCEDURE

Procedure.

15. The sample shall be dried to constant weight at a temperature of 100 to 105° C. (212 to 221° F.).

16. When cool, the bricks shall be weighed separately on scales sensitive to within 0.5 per cent.

17. The dry bricks shall be totally immersed in soft, distilled or rain water at a temperature of 15.5 to 30.0° C. (60 to 86° F.) for five hours. The bricks shall then be removed, the surface water wiped off with a damp cloth and the bricks quickly weighed.

Calculation.

18. The percentage of absorption shall be calculated on the dry weight from the formula:

$$\text{Percentage of absorption} = \frac{100\ (b - a)}{a}$$

where a = weight of dry bricks;
b = weight of saturated bricks.

TENTATIVE DEFINITIONS OF TERMS RELATING TO REFRACTORIES[1]

A.S.T.M. Designation: C 71 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927; REVISED, 1928, 1930.

Spalling.—In the case of refractories,the breaking or crushing of the unit due to thermal, mechanical or structural causes, presenting newly exposed surfaces of the residual mass.

NOTE.—The causes of spalling may be classified under three main headings: namely, thermal, mechanical and structural, as follows:

Thermal:

(*a*) *Factors Related to Service.*—Rapidity and range of thermal fluctuation; contamination by slags and fluxes; tightness of joints; previous vitrification.

(*b*) *Factors Related to Refractories.*—Degree and uniformity of reversible thermal expansion; heat transfer; elasticity; plastic flow.

Mechanical:

(*a*) *Factors Related to Service.*—Rapid heating of wet brick; abuse in removing clinker and slag; unequal and excessive stresses; pinching; no provision for expansion; thin joints.

(*b*) *Factors Related to Refractories.*—Mechanical strength; toughness; accuracy of shape.

Structural:

(*a*) *Factors Related to Service.*—Slags and fluxes; character of the material in joints; insulation of refractories.

(*b*) *Factors Related to Refractories.*—Vitrification; shrinkage; nature of bond; structure; degree of burning.

Pyrometric Cone Equivalent (*P.C.E.*).—In the case of refractories, the number of that standard cone whose tip would touch the supporting plaque simultaneously with a cone of the material being investigated when tested in accordance with the Standard Method of Test for Softening Point of Fire-Clay Brick (A.S.T.M. Designation: C 24) of the American Society for Testing Materials.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. L. J. Trostel, Secretary of Committee C-8 on Refractories, General Refractories Co. Laboratories, Box 935, Baltimore, Md.

These definitions, when adopted as standard, will be added to the Standard Definitions of Terms Relating to Refractories (A.S.T.M. Designation: C 71 – 28), 1930 Book of A.S.T.M. Standards, Part II, p. 226.

NOTE.—The terms "fusion point," "softening point" "deformation point" and "melting point" have heretofore been loosely used for "pyrometric cone equivalent."

Heat Transmission Terms

Thermal Conductivity.—The thermal conductivity of a homogeneous material is the rate of heat flow, under steady conditions, per unit area, and per unit temperature gradient, in the direction perpendicular to the area.

Thermal Resistivity.—Thermal resistivity is the reciprocal of thermal conductivity.

Resistance.—The resistance of a body between two iso-thermal surfaces is equal to the difference between the temperatures of the iso-thermal surfaces necessary to maintain unit rate of heat flow.

Conductance.—The conductance of a body between two iso-thermal surfaces is equal to the rate of heat flow through the body, per unit difference between the temperatures of the iso-thermal surfaces.

Film Resistance.—The film resistance at the boundary between a fluid and another medium in contact with it is equal to the differences between the temperature of the body of the fluid and that of the medium in contact with it, necessary to maintain unit rate of heat flow.

Surface Coefficient.—The surface coefficient at the boundary between a fluid and another medium in contact with it is equal to the rate of heat flow through the film per unit area of contact surface and unit difference between the temperature of the main body of the fluid and that of the medium in contact with it.

Total Resistance.—The total resistance to heat flow is the sum of the individual resistances through which the heat flows in series, from one medium to another.

Transmittance.—The transmittance of a system in which heat flows from one medium to another through one or more intermediate resistances, is equal to the rate of heat flow from one medium to the other divided by the difference in the temperature of the two media.

Transmission.—The transmission is the net rate of the heat flow from one medium to another, for conditions under consideration regardless of kind of transfer.

Heat Transmission Symbols

	SYMBOL
Area (normal to the path of heat flow)	A
Temperature, deg. Fahr. or deg. Cent	t
Temperature, deg. Fahr. absolute or deg. K (deg. Cent. absolute)	T
Length of path of heat flow (thickness)	L
Total quantity of heat transferred	Q
Thermal transmission (heat transferred per unit time)	q
Thermal conductivity	k

TENTATIVE SPECIFICATIONS

FOR

REINFORCED-CONCRETE PIPE[1]

A.S.T.M. Designation: C 75 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. These specifications cover reinforced concrete pipe.

Classes. 2. Pipe, under these specifications, shall be of two classes known respectively as "Standard Reinforced Concrete Pipe" and "Extra-Strength Reinforced Concrete Pipe."

Basis of Acceptance. 3. The acceptability of pipe shall be determined by the results of the strength tests specified in Sections 17 to 22, inclusive, if and when required, and by inspection to determine whether the pipe conforms to the specifications as to design and freedom from defects.

MATERIALS

Reinforced Concrete. 4. The reinforced concrete shall consist of portland cement, mineral aggregate and water in which steel has been embedded in such a manner that the steel and the concrete act together in resisting forces.

Cement. 5. Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9) of the American Society for Testing Materials.[2]

Steel. 6. Reinforcement may consist either of wire which conforms to the requirements of the Standard Specifications for Cold-Drawn Steel Wire for Concrete Reinforcement (A.S.T.M. Designation: A 82),[3] or of bars which conform to the requirements of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A.S.T.M. Designation: A 15)[1] of the American Society for Testing Materials.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. S Rankin, Secretary of Committee C-4 on Clay and Concrete Pipe, Bureau of Sewers, City Hall, Newark, N. J.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 25.

[3] 1930 Book of A.S.T.M. Standards, Part I, p. 138.

Fine Aggregate.

7. (*a*) Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances. Fine aggregate shall be well graded and shall pass a $\frac{1}{4}$-in. screen.

TABLE I.—STANDARD REINFORCED-CONCRETE PIPE.

Internal Diameter, in.	Strength Test Requirements, lb. per linear ft.				Minimum Design Requirements[a]					
	Three-Edge Bearing Method		Sand-Bearing Method		Concrete, 2750 lb. per sq. in.		Concrete, 4000 lb. per sq. in.		Concrete, 4500 lb. per sq. in.	
	Load to Produce a 0.01-in. Crack	Ultimate Load	Load to Produce a 0.01-in. Crack	Ultimate Load	Shell Thickness, in.	Total Steel Area,[b] sq.in. per linear ft.	Shell Thickness, in.	Total Steel Area,[b] sq. in. per linear ft.	Shell Thickness, in.	Total Steel Area,[b] sq. in. per linear ft.
24	1740	2675	2740	4140	3	1 Line 0.062	$2\frac{5}{8}$	1 Line 0.08	$2\frac{1}{2}$	1 Line 0.09
27	1930	2970	3045	4605	3	1 " 0.074	$2\frac{3}{4}$	1 " 0.10	$2\frac{5}{8}$	1 " 0.12
30	2110	3255	3345	5060	$3\frac{1}{2}$	1 " 0.090	3	1 " 0.12	$2\frac{3}{4}$	1 " 0.14
33	2290	3535	3635	5500	$3\frac{3}{4}$	1 " 0.116	$3\frac{1}{4}$	1 " 0.14	$2\frac{3}{4}$	1 " 0.17
36	2470	3815	3925	5940	4	1 " 0.135	$3\frac{3}{8}$	2 Lines[c] totaling 0.20	3	2 Lines[c] totaling 0.23
42	2780	4320	4470	6780	$4\frac{1}{2}$	1 " 0.153	$3\frac{3}{4}$	2 " " 0.23	$3\frac{3}{8}$	2 " " 0.27
48	3030	4740	4935	7500	5	2 Lines[c] totaling 0.210	$4\frac{1}{4}$	2 " " 0.27	$3\frac{3}{4}$	2 " " 0.32
54	3260	5130	5370	8175	$5\frac{1}{2}$	2 " " 0.250	$4\frac{5}{8}$	2 " " 0.32	$4\frac{1}{4}$	2 " " 0.38
60	3460	5475	5760	8780	6	2 " " 0.290	5	2 " " 0.38	$4\frac{1}{2}$	2 " " 0.44
66	3620	5760	6090	9300	$6\frac{1}{2}$	2 " " 0.320	$5\frac{3}{8}$	2 " " 0.44	$4\frac{3}{4}$	2 " " 0.47
72	3750	6000	6375	9750	7	2 " " 0.360	$5\frac{3}{4}$	2 " " 0.47	5	2 " " 0.55
78	....	....	....	....	$7\frac{1}{2}$	2 " " 0.400	...	....	...	....
84	....	....	....	....	8	2 " " 0.432	...	....	...	....
90	....	....	....	....	8	2 " " 0.490	...	....	...	....
96	....	....	....	....	$8\frac{1}{2}$	2 " " 0.574	...	....	...	....
108	....	....	....	....	9	2 " " 0.672	...	....	...	....

[a] The distance from the center line of the reinforcement to the nearest surface of the concrete has been assumed in the design tables as 1 in.

[b] The steel areas in this table are based on the use of cold-drawn steel wire with a value for f_s of 27,500 lb. per sq. in. If reinforcing bars of billet steel of intermediate or hard grade are used the areas of steel given in this table shall be increased 37.5 per cent to conform to a value for f_s of 20,000 lb. per sq. in. and if billet steel of structural grade is used the areas of steel given shall be increased 53 per cent to conform to a value for f_s of 18,000 lb. per sq. in.

[c] Where two lines of steel are specified, a single line placed elliptically may be used, and the area of this shall be at least 50 per cent of the total steel area specified in the design table.

Coarse Aggregate.

(*b*) Coarse aggregate shall consist of crushed stone, gravel, slag, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles, free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic, or other deleterious matter.

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 131.

Mixture. 8. The aggregates shall be so graded and proportioned and thoroughly mixed with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the concrete will conform to the test and design requirements of these specifications.

TABLE II.—EXTRA-STRENGTH REINFORCED-CONCRETE PIPE.

Internal Diameter of Pipe, in.	Strength Test Requirements, lb. per linear ft.				Minimum Design Requirements[a]			
	Three-Edge-Bearing Method		Sand-Bearing Method		Concrete, 3500 lb. per sq. in.		Concrete, 4500 lb. per sq. in.	
	Ultimate Load	Load to Produce a 0.01-in. Crack	Ultimate Load	Load to Produce a 0.01-in. Crack	Shell Thickness, in.	Total Steel Area,[b] sq. in. per linear ft.	Shell Thickness, in.	Total Steel Area,[b] sq. in. per linear ft.
24....	3185	2080	4 905	3250	3	1 Line 0.098	2⅝	1 Line 0.12
27....	3570	2330	5 505	3645	3	1 " 0.116	2¾	1 " 0.13
30....	3960	2580	6 120	4050	3½	1 " 0.135	3	1 " 0.15
33....	4330	2820	6 695	4430	3¾	1 " 0.146	3¼	1 " 0.17
36....	4700	3060	7 270	4810	4	1 " 0.173	3⅜	2 Lines[c] totaling 0.23
42....	5460	3540	8 490	5610	4½	1 " 0.187 2 Lines[c] totaling 0.242	3¾	2 " " 0.27
48....	6210	4010	9 705	6405	5	2 " " 0.270	4¼	2 " " 0.32
54....	6930	4460	10 875	7170	5½	2 " " 0.303	4⅝	2 " " 0.38
60....	7605	4880	11 980	7890	6	2 " " 0.348	5	2 " " 0.44
66....	8205	5250	12 965	8535	6½	2 " " 0.378	5⅜	2 " " 0.47
72....	8700	5550	13 800	9075	7	2 " " 0.437	5¾	2 " " 0.55
78....	....	....	.....	....	7½	2 " " 0.473	...	....
84....	....	....	.....	....	8	2 " " 0.504	...	....
90....	....	....	.....	....	8	2 " " 0.603	...	....
96....	....	....	.....	....	8½	2 " " 0.682	...	....
108....	....	....	.....	....	9	2 " " 0.820	...	....

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[a] The distance from the center line of the reinforcement to the nearest surface of the concrete has been assumed in the design tables as 1 in.

[b] The steel areas in this table are based on the use of cold-drawn steel wire with a value for f_s of 27,500 lb. per sq. in. If reinforcing bars of billet steel of intermediate or hard grade are used the areas of steel given in this table shall be increased 37.5 per cent to conform to a value for f_s of 20,000 lb. per sq. in. and if billet steel of structural grade is used the areas of steel given shall be increased 53 per cent to conform to a value for f_s of 18,000 lb. per sq. in.

[c] Where two lines of steel are specified, a single line placed elliptically may be used, and the area of this shall be at least 50 per cent of the total steel area specified in the design table.

DESIGN

Minimum Designs. 9. The shell thickness and the amount of circumferential reinforcement shall not be less than the minimum design requirements given in Tables I and II for the classes of pipe and the strength of concrete therein specified.

Alternative Designs. 10. Manufacturers may submit to the purchaser, for approval, designs based on strengths of concrete other than those given in Tables I and II. In no alternative design, however, shall the shell thickness be less nor shall the strength of concrete be less than that given in Table I.

Joints. 11. The ends of reinforced concrete pipe shall be so formed that when the pipe are laid together and the joints cemented, they shall make a continuous and uniform line of pipe with a smooth and regular interior surface. The joints shall be of such design as will permit effective cementing to reduce leakage and infiltration to a satisfactory minimum and to permit placement without appreciable irregularities in the flow line.

Placing Reinforcement. 12. When two lines of reinforcement are used in circular pipe, one shall be placed near the inner and one near the outer surfaces of the pipe. When a single line of circular reinforcement is used in circular pipe, it shall be placed near the inner surface of the pipe shell. The single line of elliptical reinforcement used in circular pipe, or the single line of circular reinforcement in elliptical pipe shall be placed near the inner surface at the "top" and "bottom" of the pipe and near the outer surface at the sides (see Section 27 (*d*)).

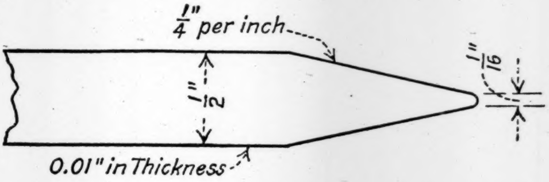


FIG. 1.—Gage Leaf for Measuring Cracks.

Longitudinals. 13. Each line of circumferential reinforcement shall be assembled into a cage and have sufficient longitudinal bars or members, extending through the barrel of the pipe, to afford rigidity and maintain the reinforcement in exact shape.

Laps and Welds. 14. The reinforcement shall be lapped not less than 30 diameters, or if welded, the joints shall develop the full strength of the reinforcement. The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. up to and including pipe 48 in. in diameter, nor exceed the shell thickness for larger pipe and shall in no case exceed 6 in.

PHYSICAL TEST REQUIREMENTS

Strength Requirements. 15. The ultimate load, as determined by either of the methods described in Section 21, shall not be less than the ultimate loads given in Tables I and II for the size and class of pipe being tested. When the test load reaches the cracking load given in Tables I and II for the size and class of pipe being tested, there shall be in the barrel of the pipe no crack having a surface width of 0.01 in. or more (see

Note), for a length of 1 ft. or more. The ultimate load is reached when the pipe will sustain no greater load.

NOTE.—It is recommended that the width of the crack be measured by means of a gage made from a leaf 0.01 in. in thickness from a set of standard machinists' gages, ground to a point of $\frac{1}{16}$ in. in width, with corners rounded, and with a taper of $\frac{1}{4}$ in. per inch, as illustrated by Fig. 1. The crack shall be considered to be 0.01 in. in width when the point of the gage will just enter it at close intervals.

Elliptical Pipe.

16. Elliptical pipe shall conform to the test requirements for circular pipe having the same horizontal internal diameter.

PHYSICAL TESTS

Strength Tests and Inspection.

17. Pipe 24 to 72 in. in diameter shall be tested for strength as provided in Sections 19, 20 and 21, or the purchaser may elect to accept all pipe with respect to strength on the basis of cylinder tests of the concrete as provided in Section 22. When strength tests are required on pipe larger than 72 in. in diameter, the purchaser shall so specify in the order.

Specimen for Strength Test.

18. The specimens for the strength test shall be full size pipe which shall in every respect conform to the inspection requirements specified in Section 29.

Selection of Specimens for Strength.

19. The specimens to be tested for strength shall be representative and shall be selected by the purchaser or his representative at the point or points designated by him when placing the order. The manufacturer shall furnish for testing purposes and at his own expense, one pipe of each size included in the order; the purchaser bearing all expense of testing such pipe. Should additional tests be made upon the demand of the purchaser or manufacturer, then cost of such additional test specimens and the expense of testing shall be borne by the party making such demand.

Complying with Strength Tests.

20. (*a*) Should the test specimens selected by the purchaser conform to the test requirements, then all pipe represented by such specimens shall be accepted as to strength, provided the pipe shall otherwise conform to the specifications.

(*b*) Should any of the specimens first tested fail to conform to the test requirements, then the manufacturer shall have the right to additional tests of the size or sizes of pipe which have failed. If the strength attained by a specimen is less than the strength required, in the amounts shown in the first column of the following table, additional tests shall be made upon pipe to the number specified below, for each pipe of deficient strength:

PERCENTAGE OF REQUIRED STRENGTH	NUMBER OF PIPE FOR RETEST
Less than 100 per cent and more than 90 per cent	2
" " 90 " " " " 80 "	3
" " 80 " " " " 70 "	4

If the additional pipe so tested all conform to the test requirements, then all pipe represented by such tests shall be accepted; otherwise they shall be rejected, unless other tests, mutually agreed upon between the purchaser and manufacturer, demonstrate to the satisfaction of the purchaser, the acceptability of the pipe. This latter provision, as to tests by agreement, shall also apply in the event that the strength attained by a pipe under test is less than 70 per cent of the required strength.

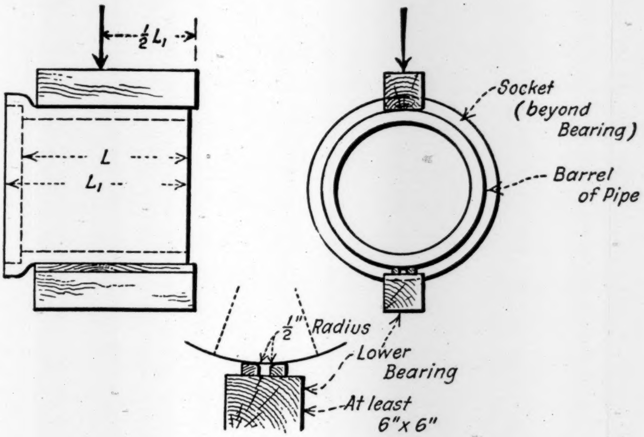

½ L₁
L
L₁
Socket (beyond Bearing)
Barrel of Pipe
½" Radius
Lower Bearing
At least 6" x 6"

FIG. 2.—Three-Edge Bearings.

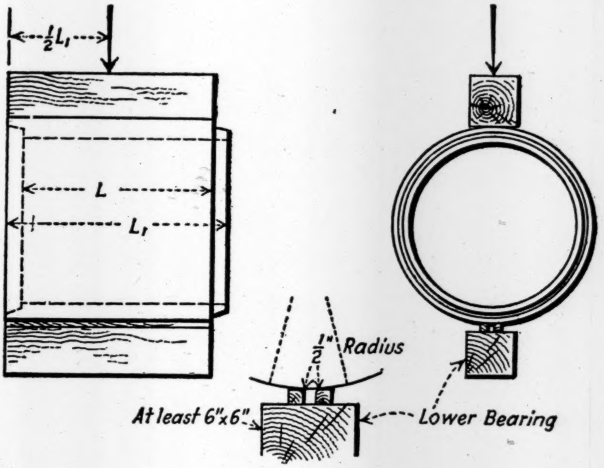

½ L₁
L
L₁
½" Radius
At least 6" x 6"
Lower Bearing

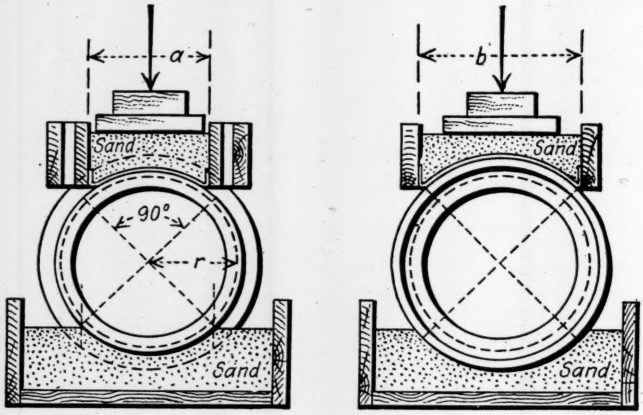
FIG. 3.—Three-Edge Bearings.

Strength Tests.

21. Pipe may be tested for strength by either the three-edge-bearing or sand-bearing method.

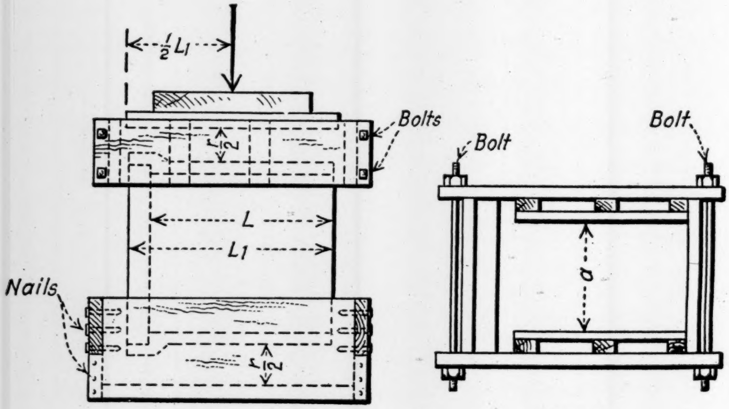
Three-Edge-Bearing Method.

(*a*) When the three-edge bearing method is used, the lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ in. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical sides spaced a distance apart of not more than 1 in. for each foot of pipe diameter. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive



Bedding of Barrel.

Bedding of Socket.



Side View.

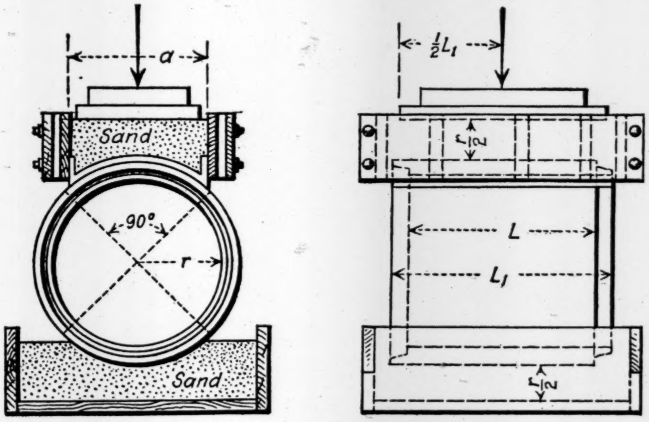
Upper Bearing Frame.

FIG. 4.—Sand Bearings.

of bell. The pipe shall be placed symmetrically between the two bearings as illustrated in Figs. 2 and 3. In testing pipe which is "out of line" the lines of the bearings chosen shall be from those which appear to give the most favorable conditions for fair test.

Sand-Bearing Method.

(*b*) When the sand-bearing method is used (see Figs. 4 and 5), the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.



Bedding of Barrel.

FIG. 5.—Sand Bearings.

The sand used shall be clean and moist, and shall be such as will pass a 4760-micron (No. 4) sieve.[1] The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come in contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck off level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.

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[1] For requirements for this sieve, see the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, 1930 Book of A.S.T.M. Standards, Part II, p. 1119.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Testing Apparatus.

(*c*) It is desirable that the testing machine used for the strength tests shall give a uniform deflection throughout the full length of the pipe. Any mechanical or hand power device in which the head that applies the load moves at a speed of not more than 0.05 in. per minute or a machine which will apply the load at a uniform rate of 500 lb. per linear foot of pipe per minute may be used in making the test. The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the required strength of the pipe is reached.

Cylinder Tests and Reinforcement Examination.

22. The quality of the pipe may be determined by tests of the quality of concrete as placed in the pipe and examination of the quality, amount and accuracy of placement of the reinforcement. The quality of the concrete shall be determined on 6 by 12-in. test cylinders, taken from the concrete used in making the pipe and manufactured and cured under identical conditions with the pipe. Compression tests of these cylinders, determined in accordance with the Standard Method of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39) of the American Society for Testing Materials,[1] shall show an average strength of not less than the strength test requirements given in Tables I and II at 28 days and not less than 50 per cent of these strengths at 7 days, and not more than 10 per cent of the total number of cylinders tested shall show a strength of less than 80 per cent of these amounts. The position of the reinforcement shall conform to the requirements specified in Section 12.

Test Equipment.

23. Every manufacturer furnishing pipe under these specifications shall furnish all facilities necessary to carry out the tests required in these specifications.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 143.

SIZE AND PERMISSIBLE VARIATIONS

Standard Sizes.

24. Pipe of the internal diameters listed in Tables I and II shall be considered standard sizes. In elliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

Variations in Dimensions.

25. (*a*) Variations of the internal diameter shall not exceed 1.5 per cent for 24 to 36-in. pipe, inclusive, and 1 per cent for 42 to 108-in. pipe, inclusive. The shell thickness shall not be less than that given in Tables I and II by more than 5 per cent at any point.

(*b*) Variations in the position of the reinforcement cages shall not exceed $\frac{1}{4}$ in. for 24 to 33-in. pipe, inclusive, nor $\frac{1}{2}$ in. for 36 to 108-in. pipe, inclusive, from the position provided in the design, nor shall the thickness of concrete over the reinforcement be less than $\frac{3}{4}$ in. at any point.

WORKMANSHIP AND FINISH

Finish.

26. Pipe shall be substantially free from fractures, large or deep cracks and surface roughness. The planes of the ends of the pipe shall be perpendicular to their longitudinal axes.

MARKING

Markings.

27. The following shall be clearly stenciled on the pipe:

(*a*) The pipe class $\begin{cases}\text{by an “S” for Standard Pipe; and}\\ \text{by an “X” for Extra-Strength Pipe;}\end{cases}$

(*b*) The date of manufacture;

(*c*) The name or trade-mark of the manufacturer;

(*d*) Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the word “Top” or “Bottom” clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

INSPECTION AND REJECTION

Minimum Age for Shipment.

28. Pipe shall be considered ready for shipment when they conform to the test requirements, or when tests of 6 by 12-in. cylinders (Section 22) show that the concrete has attained the strength assumed in the design of the pipe.

Inspection.

29. All materials, processes of manufacture and finished pipe shall be subject to inspection and approval by an inspector employed by the purchaser. The manufacturer, when so directed by the inspector, shall have holes cut in such sections of the finished pipe (not exceeding one hole in every 50 sections delivered) as desired so that a proper

inspection may be made of the quantity and placement of the reinforcement. If the pipes are tested for strength, inspection of the reinforcement may be made on the pipe used for those tests, and in no case shall the total number of pipe cut open for inspection of reinforcement exceed the number to which the purchaser is entitled under the provisions of Sections 19 and 20.

Causes for Rejection of Pipe.

30. Pipe shall be subject to rejection on account of failure to conform to any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell, except that an end crack that does not exceed the depth of the joint, or a fracture that at its deepest point does not exceed the depth of the joint nor extend more than 10 per cent around the circumference shall not be considered cause for rejection unless these defects exist in more than 5 per cent of the pipe inspected.

(*b*) Defects which indicate imperfect mixing, placing and curing concrete.

(*c*) Exposure of the reinforcement when such exposure would indicate that the reinforcement is misplaced.

TENTATIVE SPECIFICATIONS

FOR

REINFORCED-CONCRETE CULVERT PIPE[1]

A.S.T.M. Designation: C 76 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions; and as such is subject to annual revision.

Issued, 1930.

Scope. 1. These specifications cover reinforced concrete pipe intended to be used for the construction of culverts.

Classes. 2. Pipe, under these specifications, shall be of two classes known respectively as "Standard Reinforced Concrete Culvert Pipe" and "Extra-Strength Reinforced Concrete Culvert Pipe."

Basis of Acceptance 3. The acceptability of pipe shall be determined by the results of the strength and absorption tests specified in Sections 17 to 19, inclusive, if and when required, and by inspection to determine whether the pipe conforms to the specifications as to design, and freedom from defects.

MATERIALS

Reinforced Concrete. 4. The reinforced concrete shall consist of portland cement, mineral aggregate and water in which steel has been embedded in such a manner that the steel and the concrete act together in resisting forces.

Cement. 5. Portland cement shall conform to the requirements of the Standard Specifications for Portland Cement (A.S.T.M. Designation: C 9) of the American Society for Testing Materials.[2]

Steel. 6. Reinforcement may consist either of wire which conforms to the requirements of the Standard Specifications for Cold-Drawn Steel

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. E. S. Rankin, Secretary of Committee C-4 on Clay and Concrete Pipe, Bureau of Sewers, City Hall, Newark, N. J.

These specifications, in substance, are those prepared by the Joint Concrete Culvert Pipe Committee, and submitted by the Joint Committee to the Society in 1928. The following organizations are represented on the Joint Committee: Bureau of Public Roads, American Society of Civil Engineers American Association of State Highway Officials, American Railway Engineering Association, American Concrete Institute, American Concrete Pipe Association, and the American Society for Testing Materials.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 25.

Wire for Concrete Reinforcement (A.S.T.M. Designation: A 82),[1] or of bars which conform to the requirements of the Standard Specifications for Billet-Steel Concrete Reinforcement Bars (A.S.T.M. Designation: A 15)[2] of the American Society for Testing Materials.

Fine Aggregate. 7. (*a*) Fine aggregate shall consist of sand, stone screenings, or other inert materials with similar characteristics, or a combination thereof, having clean, hard, strong, durable, uncoated grains and free from injurious amounts of dust, lumps, soft or flaky particles, shale, alkali, organic matter, loam or other deleterious substances. Fine aggregate shall be well graded and shall pass a $\frac{1}{4}$-in. screen.

Coarse Aggregate. (*b*) Coarse aggregate shall consist of crushed stone, gravel, slag, or other approved inert materials with similar characteristics, or combinations thereof, having clean, hard, strong, durable, uncoated particles, free from injurious amounts of soft, friable, thin, elongated or laminated pieces, alkali, organic or other deleterious matter.

Mixture. 8. The aggregates shall be so graded and proportioned and thoroughly mixed with such proportions of cement and water as will produce a homogeneous concrete mixture of such quality that the concrete will conform to the test and design requirements of these specifications.

DESIGN

Methods of Design. 9. The pipe shall be designed in accordance with the following assumptions:

(*a*) That the design load is equivalent to a vertical load uniformly distributed over the internal horizontal projection of the pipe, that the pipe is likewise uniformly supported and that no allowance is made for side pressure.

(*b*) The uniform load for the "Standard Reinforced Concrete Culvert Pipe" shall be 2000 lb. per sq. ft. and for the "Extra-Strength Reinforced Concrete Culvert Pipe" 4000 lb. per sq. ft. respectively.

(*c*) The working stress per square inch in compression for the concrete shall not exceed three-eighths of the strength of concrete upon which the design is based.

(*d*) The ratio, n, of the modulus of elasticity of steel to that of concrete shall be 12 for concrete having an ultimate compressive strength at 28 days of 2750 lb. per sq. in. and 9 for concrete having an ultimate compressive strength of 4000 lb. per sq. in. or greater. Intermediate values of n shall be proportional to the strength of concrete assumed in the design.

(*e*) The working stress for cold-drawn steel wire shall not exceed 27,500 lb. per sq. in. For billet-steel, intermediate and hard grades, the working stress shall not exceed 20,000 lb. per sq. in.; and for billet-steel, structural grade, the working stress shall not exceed 18,000 lb. per sq. in.

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[1] 1930 Book of A.S.T.M. Standards, Part I, p. 138.

[2] *Ibid.*, p. 131.

(*f*) The distance from the center of the reinforcement to the nearest or tension surface of the concrete shall not be less than $\frac{3}{4}$ in. for pipe 12 in. or less in diameter, or less than 1 in. for pipe over 12 in. in diameter.

(*g*) The distance from the center of the tension reinforcement to the compression surface of the concrete and the area of the reinforcement shall not be less than that required by the formula:

$$\frac{wd}{16} \times \frac{d+t}{12} = jAtf_s$$

where w = the uniform vertical load in pounds per square foot, top and bottom of pipe;

d = the internal diameter of pipe in inches;

t = the distance from the center of the tension reinforcement to the compression surface of the concrete in inches;

A = the sectional area of tension reinforcement in square inches per lineal foot of the pipe;

f_s = the tensile stress in the reinforcement in pounds per square inch; and

j = the ratio of the lever arm of the reinforcement to "t" as determined by the usual formulas.

Minimum Designs.

10. The shell thickness and the amount of circumferential reinforcement shall not be less than that given in the design tables for the classes and sizes of pipe and the strength of concrete therein specified.

Alternative Designs.

11. Manufacturers may submit to the purchaser, for approval, designs based on strengths of concrete other than those given in the design tables. Such alternate designs shall comply with the design requirements given in Sections 9 and 10. In no alternative design, however, shall the shell thickness be less than those given in Table II, nor shall the strength of concrete be less than that given in Table I.

Joints.

12. The ends of the pipe shall be of such design that the pipe when laid shall make a continuous conduit with a smooth and uniform interior surface.

Placing Reinforcement

13. When a single line of circular reinforcement is used in circular pipe, it shall be placed at the center of the pipe shell. When two lines of reinforcement are used in circular pipe, one shall be placed near the inner and one near the outer surface of the pipe. The single line of elliptical reinforcement used in circular pipe, or the single line

TABLE I.—DESIGN DATA FOR STANDARD REINFORCED-CONCRETE CULVERT PIPE. Uniform Load of 2000 lb. per sq. ft.; Compressive Strength of Concrete, 2750 lb. per sq. in.; f_c = 1030 lb. per sq. in.

Internal Diameter, d, of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance, t, Center of Reinforcement to Compressive Surface, in.		Minimum Area, A, of Circumferential Reinforcement, sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire $f_s = 27\,500$ lb. per sq. in.		Billet-Steel Hard and Intermediate Grades $f_s = 20\,000$ lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12........	2	1	..	1 Line 0.07	....	1 Line 0.09	....
15........	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.09	1 Line 0.08	1 " 0.13	1 Line 0.12
18........	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 " 0.12	1 " 0.10	1 " 0.17	1 " 0.14
24........	3	$1\frac{1}{2}$	2	1 " 0.17	1 " 0.13	1 " 0.25	1 " 0.19
30........	$3\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{2}$	1 " 0.23	1 " 0.17	1 " 0.32	1 " 0.23
30........	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2 " each 0.17	1 " 0.17	2 " each 0.23	1 " 0.23
36........	4	3	3	2 " " 0.20	1 " 0.20	2 " " 0.28	1 " 0.28
42........	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	2 " " 0.23	1 " 0.23	2 " " 0.32	1 " 0.32
48........	5	4	4	2 " " 0.26	1 " 0.26	2 " " 0.37	1 " 0.37
54........	$5\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	2 " " 0.30	1 " 0.30	2 " " 0.42	1 " 0.42
60........	6	5	5	2 " " 0.33	1 " 0.33	2 " " 0.46	1 " 0.46
72........	7	6	6	2 " " 0.40	1 " 0.40	2 " " 0.56	1 " 0.56
84........	8	7	7	2 " " 0.46	1 " 0.46	2 " " 0.65	1 " 0.65

TABLE II.—DESIGN DATA FOR STANDARD REINFORCED-CONCRETE CULVERT PIPE. Uniform Load of 2000 lb. per sq. ft.; Compressive Strength of Concrete, 4000 lb. per sq. in.; f_c = 1500 lb. per sq. in.

Internal Diameter, d, of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance, t, Center of Reinforcement to Compressive Service, in.		Minimum Area, A, of Circumferential Reinforcement. sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire $f_s = 27\,500$ lb. per sq. in.		Billet-Steel Hard and Intermediate Grades $f_s = 20\,000$ lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12........	$1\frac{3}{4}$	$\frac{7}{8}$	..	1 Line 0.08	....	1 Line 0.11	....
15........	2	1	..	1 " 0.11	....	1 " 0.15	....
18........	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.14	1 Line 0.12	1 " 0.19	1 Line 0.17
24........	$2\frac{5}{8}$	$1\frac{1}{4}$	$1\frac{5}{8}$	1 " 0.21	1 " 0.17	1 " 0.30	1 " 0.23
30........	3	$1\frac{1}{2}$	2	1 " 0.29	1 " 0.21	1 " 0.38	1 " 0.29
30........	3	2	2	2 " each 0.21	1 " 0.21	2 " each 0.29	1 " 0.29
36........	$3\frac{3}{8}$	$3\frac{3}{8}$	$2\frac{3}{8}$	2 " " 0.26	1 " 0.26	2 " " 0.36	1 " 0.36
42........	$3\frac{3}{4}$	$2\frac{3}{4}$	$2\frac{3}{4}$	2 " " 0.30	1 " 0.30	2 " " 0.41	1 " 0.41
48........	$4\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{4}$	2 " " 0.34	1 " 0.34	2 " " 0.46	1 " 0.46
54........	$4\frac{5}{8}$	$3\frac{5}{8}$	$3\frac{5}{8}$	2 " " 0.38	1 " 0.38	2 " " 0.52	1 " 0.52
60........	5	4	4	2 " " 0.42	1 " 0.42	2 " " 0.59	1 " 0.59
72........	$5\frac{3}{4}$	$4\frac{3}{4}$	$4\frac{3}{4}$	2 " " 0.51	1 " 0.51	2 " " 0.71	1 " 0.71
84........	$6\frac{5}{8}$	$5\frac{5}{8}$	$5\frac{5}{8}$	2 " " 0.60	1 " 0.60	2 " " 0.82	1 " 0.82

of circular reinforcement in elliptical pipe shall be placed near the inner surface at the "top" and "bottom" of the pipe and near the outer surface at the sides (see Section 31 (*d*)).

Longitudinals. 14. Each line of circumferential reinforcement shall be assembled into a cage and have sufficient longitudinal bars or members, extending through the barrel of the pipe, to afford rigidity and maintain the reinforcement in exact shape and correct position within the form.

Laps and Welds. 15. The reinforcement shall be lapped not less than 30 diameters, or if welded, the joints shall develop the full strength of the reinforcement. The spacing center to center of adjacent rings of circumferential reinforcement in a cage shall not exceed 4 in. up to and including pipe 48 in. in diameter, nor exceed the shell thickness for larger pipe and shall in no case exceed 6 in.

Bell Reinforcement. 16. The bell shall have a circumferential reinforcement equal in unit area to that of a single line within the barrel of the pipe.

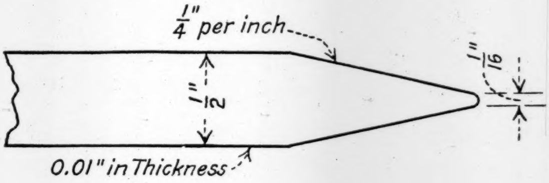


FIG. 1.—Gage Leaf for Measuring Cracks.

PHYSICAL TEST REQUIREMENTS

Strength Requirements. 17. The ultimate load, as determined by one of the methods described in Section 20, shall not be less than the ultimate load specified in Table V for the size and class of pipe being tested. When the test load reaches the cracking load given in Table V for the size and class of pipe being tested, there shall be in the barrel of the pipe no crack having a surface width of 0.01 in. or more (see Note), for a length of 1 ft. or more. The ultimate load is reached when the pipe will sustain no greater load.

NOTE.—It is recommended that the width of the crack be measured by means of a gage made from a leaf 0.01 in. in thickness from a set of standard machinists' gages, ground to a point $\frac{1}{16}$ in. in width, with corners rounded, and with a taper of $\frac{1}{4}$ in. per inch, as illustrated by Fig. 1. The crack shall be considered to be 0.01 in. in width when the point of the gage will just enter it at close intervals.

Elliptical Pipe. 18. Elliptical pipe shall conform to the test requirements for circular pipe having the same horizontal internal diameter.

Test Requirements and Acceptability Under Absorption Tests.

19. The absorption shall not exceed 8 per cent for test specimens taken from pipe designed to be made of concrete having a compressive strength of 3000 lb. per sq. in. or more, or 9 per cent for test specimens taken from pipe designed for a compressive strength of less than 3000 lb. per sq. in. Pipe shall be considered as conforming to these specifications for absorption when not less than 80 per cent of the number of specimens tested, including any retested, conform to the test requirements. When the initial absorption specimen from a pipe fails to conform to these specifications, the absorption test shall be made on another specimen from the same pipe and the results of the retest shall be substituted for the original test results.

TABLE III.—DESIGN DATA FOR EXTRA-STRENGTH REINFORCED-CONCRETE CULVERT PIPE.

Uniform Load of 4000 lb. per sq. ft.; Compressive Strength of Concrete, 2750 lb. per sq. in.; f_c = 1030 lb. per sq. in.

Internal Diameter, *d*, of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance, *t*, Center of Reinforcement to Compressive Surface, in		Minimum Area, *A*, of Circumferential Reinforcement, sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire f_s = 27 500 lb. per sq. in.		Billet-Steel Hard and Intermediate Grades f_s = 20 000 lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12........	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 Line 0.11	1 Line 0.09	1 Line 0.15	1 Line 0.13
15........	$2\frac{3}{4}$	$1\frac{3}{8}$	$1\frac{3}{4}$	1 " 0.15	1 " 0.12	1 " 0.21	1 " 0.17
18........	$3\frac{1}{8}$	$1\frac{5}{8}$	$2\frac{1}{8}$	1 " 0.18	1 " 0.14	1 " 0.26	1 " 0.20
24........	$3\frac{7}{8}$	2	$2\frac{7}{8}$	1 " 0.26	1 " 0.19	1 " 0.37	1 " 0.27
30........	$4\frac{5}{8}$	$2\frac{1}{4}$	$3\frac{5}{8}$	1 " 0.36	1 " 0.23	1 " 0.51	1 " 0.33
30........	$4\frac{5}{8}$	$3\frac{5}{8}$	$3\frac{5}{8}$	2 " each 0.23	1 " 0.23	2 " each 0.33	1 0.33
36........	$5\frac{3}{8}$	$4\frac{3}{8}$	$4\frac{3}{8}$	2 " " 0.28	1 " 0.28	2 " " 0.40	1 " 0.40
42........	6	5	5	2 " " 0.33	1 " 0.33	2 " " 0.47	1 " 0.47
48........	$6\frac{3}{4}$	$5\frac{3}{4}$	$5\frac{3}{4}$	2 " " 0.38	1 " 0.38	2 " " 0.53	1 " 0.53
54........	$7\frac{1}{2}$	$6\frac{1}{2}$	$6\frac{1}{2}$	2 " " 0.42	1 " 0.42	2 " " 0.60	1 " 0.60
60........	$8\frac{1}{4}$	$7\frac{1}{4}$	$7\frac{1}{4}$	2 " " 0.47	1 " 0.47	2 " " 0.66	1 " 0.66
72........	$9\frac{5}{8}$	$8\frac{5}{8}$	$8\frac{5}{8}$	2 " " 0.57	1 " 0.57	2 " " 0.80	1 " 0.80
84........	11	10	10	2 " " 0.67	1 " 0.67	2 " " 0.94	1 " 0.94

PHYSICAL TESTS

(*A*) *Strength Tests*

Strength Tests.

20. Pipe may be tested for strength by either the three-edge-bearing or sand-bearing method:

TABLE IV.—DESIGN DATA FOR EXTRA-STRENGTH REINFORCED-CONCRETE CULVERT PIPE.

Uniform Load of 4000 lb. per sq. ft.; Compressive Strength of Concrete, 4750 lb. per sq. in.; f_c = 1780 lb. per sq. in.

Internal Diameter, d, of Pipe, in.	Minimum Thickness of Shell, in.	Minimum Distance, t, Center of Reinforcement to Compressive Surface, in.		Mimimum Area, A, of Circumferential Reinforcement, sq. in. per linear foot of pipe			
				Cold-Drawn Steel Wire f_s = 27 500 lb. per sq. in.		Billet-Steel Hard and Intermediate Grades f_s = 20 000 lb. per sq. in.	
		Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe	Circular Reinforcement in Circular Pipe	Elliptical Reinforcement in Circular Pipe and Circular Reinforcement in Elliptical Pipe
12........	2	1	..	1 Line 0.14	....	1 Line 0.19	....
15........	$2\frac{1}{4}$	$1\frac{1}{8}$	$1\frac{1}{4}$	1 " 0.19	1 Line 0.17	1 " 0.26	1 Line 0.24
18........	$2\frac{1}{2}$	$1\frac{1}{4}$	$1\frac{1}{2}$	1 " 0.24	1 " 0.21	1 " 0.34	1 " 0.29
24........	3	$1\frac{1}{2}$	2	1 " 0.35	1 " 0.27	1 " 0.50	1 " 0.39
30........	$3\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{2}$	1 " 0.47	1 " 0.34	1 " 0.66	1 " 0.48
30........	$3\frac{1}{2}$	$2\frac{1}{2}$	$2\frac{1}{2}$	2 " each 0.34	1 " 0.34	2 " each 0.48	1 " 0.48
36........	4	3	3	2 " " 0.41	1 " 0.41	2 " " 0.57	1 " 0.57
42........	$4\frac{1}{2}$	$3\frac{1}{2}$	$3\frac{1}{2}$	2 " " 0.48	1 " 0.48	2 " " 0.67	1 " 0.67
48........	5	4	4	2 " " 0.55	1 " 0.55	2 " " 0.76	1 " 0.76
54........	$5\frac{1}{2}$	$4\frac{1}{2}$	$4\frac{1}{2}$	2 " " 0.62	1 " 0.62	2 " " 0.86	1 " 0.86
60........	6	5	5	2 " " 0.68	1 " 0.68	2 " " 0.95	1 " 0.95
72........	7	6	6	2 " " 0.82	1 " 0.82	2 " " 1.14	1 " 1.14
84........	8	7	7	2 " " 0.96	1 " 0.96	2 " " 1.33	1 " 1.33

TABLE V.—MINIMUM STRENGTH OF REINFORCED-CONCRETE CULVERT PIPE IN POUNDS PER FOOT OF LAYING LENGTH.

Size of Pipe, in.	Standard Reinforced-Concrete Culvert Pipe				Extra-Strength Reinforced-Concrete Culvert Pipe			
	3-Edge Bearing Method		Sand-Bearing Method		3-Edge Bearing Method		Sand-Bearing Method	
	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load	Cracking Load[a]	Ultimate Load
12.........	1 600	2 000	2 400	3 000	3 200	4 000	4 800	6 000
15.........	1 800	2 500	2 700	3 750	3 600	5 000	5 400	7 500
18.........	2 000	3 000	3 000	4 500	4 000	6 000	6 000	9 000
24.........	2 200	4 000	3 300	6 000	4 400	8 000	6 600	12 000
30.........	2 500	5 000	3 750	7 500	5 000	10 000	7 500	15 000
36.........	3 000	6 000	4 500	9 000	6 000	12 000	9 000	18 000
42.........	3 500	7 000	5 250	10 500	7 000	14 000	10 500	21 500
48.........	4 000	8 000	6 000	12 000	8 000	16 000	12 000	24 000
54.........	4 500	9 000	6 750	13 500	9 000	18 000	13 500	27 000
60.........	5 000	10 000	7 500	15 000	10 000	20 000	15 000	30 000
72.........	6 000	12 000	9 000	18 000	12 000	24 000	18 000	36 000
84.........	7 000	14 000	10 500	21 000	14 000	28 000	21 000	42 000

[a] At the cracking load there shall be, in the barrel of the pipe, no crack having a surface width of 0.01 in. or more for a length of 1 ft. or more.

Three-Edge-Bearing Method.

(*a*) When the three-edge-bearing method is used, the lower bearing for the pipe shall consist of two wooden strips with vertical sides having their interior top corners rounded to a radius of approximately ½ in. The strips shall be straight and shall be securely fastened to a rigid block with the interior vertical sides spaced a distance apart not less than ½ in. or more than 1 in. for each foot of pipe diameter. The upper bearing shall be a rigid wooden block, straight and true from end to end. The upper and lower bearings shall extend the full length of pipe exclusive of bell. The pipe shall be placed

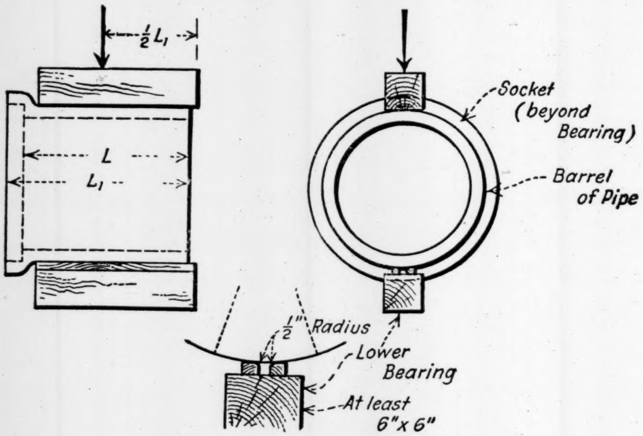

½L₁
L
L₁
Socket (beyond Bearing)
Barrel of Pipe
½" Radius
Lower Bearing
At least 6"x 6"

FIG. 2.—Three-Edge Bearings.

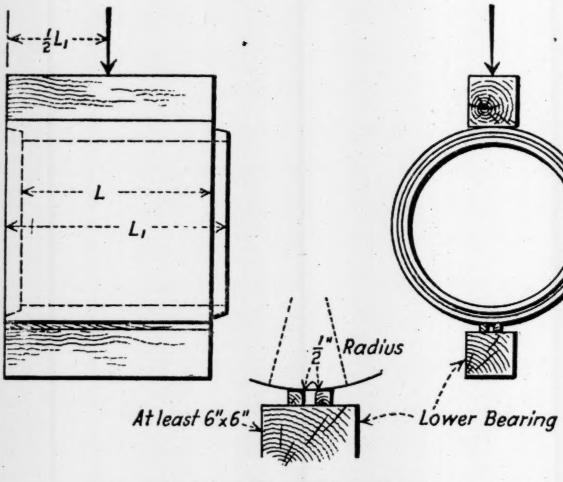
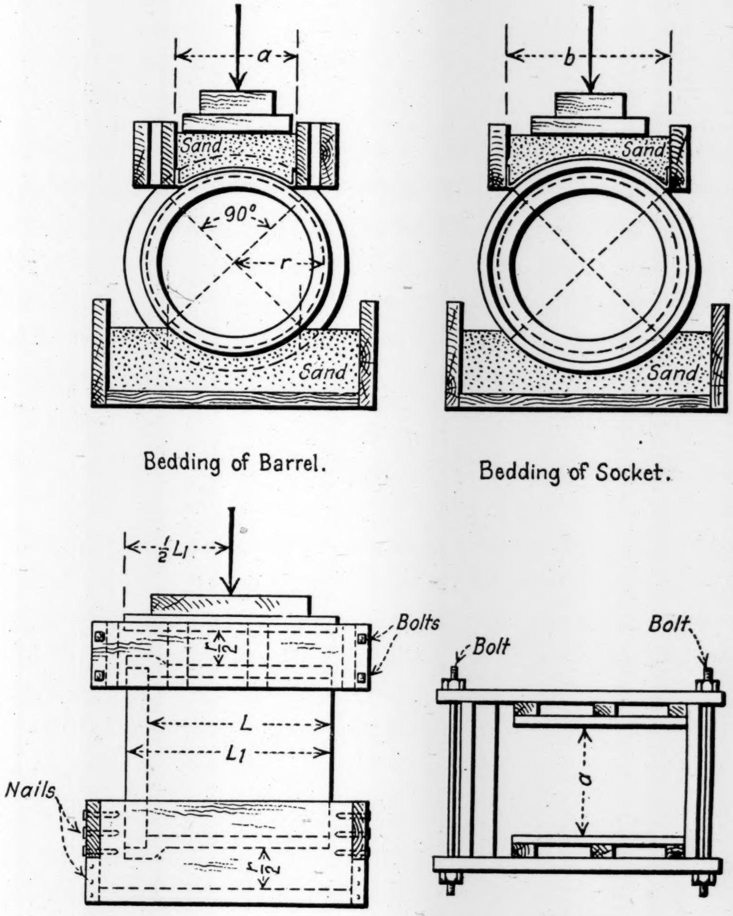

½L₁
L
L₁
½" Radius
At least 6"x6"
Lower Bearing

FIG. 3.—Three-Edge Bearings.

symmetrically between the two bearings as illustrated in Figs. 2 and 3. In testing pipe which is "out of line" the lines of the bearings chosen shall be from those which appear to give the most favorable conditions for fair test.



Bedding of Barrel.

Bedding of Socket.

Side View.

Upper Bearing Frame.

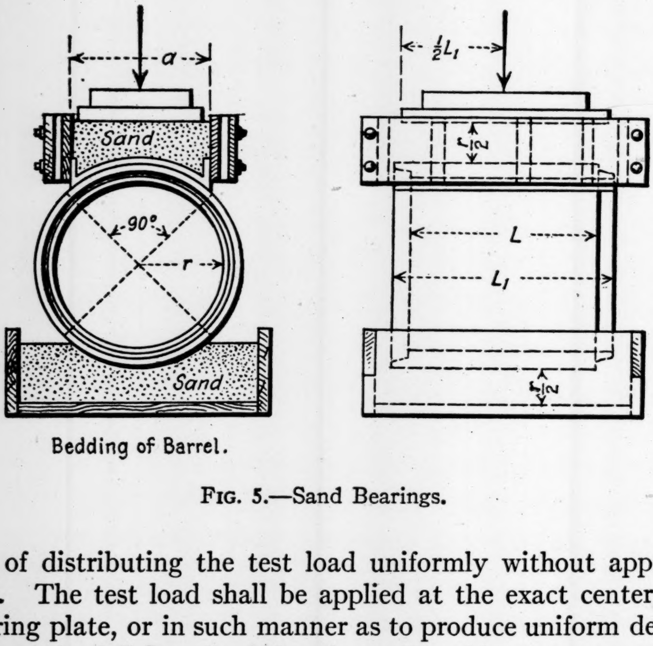
FIG. 4.—Sand Bearings.

Sand-Bearing Method.

(*b*) When the sand-bearing method is used (see Figs. 4 and 5), the ends of each specimen of pipe shall be accurately marked prior to the test in quarters of the circumference. Specimens shall be carefully bedded, above and below, in sand, for one-fourth the circumference of the pipe measured on the middle line of the barrel. The depth of bedding above and below the pipe at the thinnest points shall be one-half the radius of the middle line of the barrel.

The sand used shall be clean and moist, and shall be such as will pass a 4760-micron (No. 4) sieve.[1] The sand in the lower bearing shall be loose when the pipe is placed.

The top bearing frame shall not be allowed to come into contact with the pipe nor with the top bearing plate. The upper surface of the sand in the top bearing shall be struck off level with a straight edge, and shall be covered with a rigid top bearing plate, with lower surface a true plane, made of heavy timbers or other rigid material, capable of distributing the test load uniformly without appreciable bending. The test load shall be applied at the exact center of this top bearing plate, or in such manner as to produce uniform deflection throughout the full length of the pipe. For this purpose a spherical bearing is preferred, but two rollers at right angles may be used. The test may be made without the use of a testing machine, by piling weights directly on a platform resting on the top bearing plate, provided, however, that the weights shall be piled symmetrically about a vertical line through the center of the pipe, and that the platform shall not be allowed to touch the top bearing frame.



Bedding of Barrel.

FIG. 5.—Sand Bearings.

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[1] For requirements of this sieve, see the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, 1930 Book of A.S.T.M. Standards, Part II, p. 1119.

The frames of the top and bottom bearings shall be made of timbers so heavy as to avoid appreciable bending by the side pressure of sand. The interior surfaces of the frames shall be dressed. No frame shall come in contact with the pipe during the test. A strip of cloth may, if desired, be attached to the inside of the upper frame on each side, along the lower edge, to prevent the escape of sand between the frame and the pipe.

Testing Apparatus.

(*c*) It is desirable that the testing machine used for the strength tests shall give a uniform deflection throughout the full length of the pipe. Any mechanical or hand power device may be used in which the head that applies the load moves at a speed of not more than 0.05 in. per minute while making the test. The testing machine shall be substantial and rigid throughout, so that the distribution of the load will not be affected appreciably by the deformation or yielding of any part. The load shall be applied continuously until the ultimate strength of the pipe is reached.

Preliminary Tests and Tests for Extended Deliveries.

21. Preliminary to placing an order, a purchaser of pipe whose needs require shipments at intervals over extended periods of time shall be entitled to test not more than ten pieces of pipe covering the size in which he is interested. The test specimens shall be selected in approximately equal numbers from the larger and smaller sizes of pipe. The acceptability of the larger sizes of pipe shall not be based on the results of tests in smaller sizes. After these preliminary tests, a purchaser shall be entitled to additional tests in such numbers and at such times as he may deem necessary, provided that the total number of pipe tested shall not exceed 2 per cent of the total deliveries.

Tests for Occasional Orders.

22. A purchaser who places occasional orders shall be entitled to test a number of pipe equal to 2 per cent of an order but not to exceed five pieces of any one size; otherwise the number of pipe desired for testing shall be included in the order.

Selecting Test Specimens.

23. All pipe for testing purposes shall be selected at random by the purchaser from the stock of the manufacturer and shall be pipe which would not otherwise be rejected under these specifications. The pipe shall be free from visible moisture when tested and they shall not have been exposed to a temperature below 40° F. for the 24 hours immediately preceding the test.

Cylinder Tests and Reinforcement Examinations.

24. By agreement between the purchaser and the manufacturer the continued acceptability of the pipe, after the preliminary pipe tests have been made, may be determined by tests of the quality of the concrete as placed in the pipe and examination of the quality, amount and the accuracy of placement of the reinforcement. The

quality of the concrete shall be determined on 6 by 12-in. test cylinders taken from the concrete used in making the pipe and manufactured and cured under identical conditions with the pipe. When tested in accordance with the Standard Methods of Making Compression Tests of Concrete (A.S.T.M. Designation: C 39) of the American Society for Testing Materials,[1] these cylinders shall have a strength not less than that assumed in the design of the pipe.

Retests. 25. Pipe shall be acceptable under the strength tests when all test specimens conform to the test requirements. Should less than three of the ten preliminary test specimens or any one of the additional test specimens provided for in Section 21, or any one specimen provided for in Section 22 fail to meet the test requirements, then the manufacturer will be allowed a retest on two like specimens for each specimen that failed, and the pipe shall be acceptable only when all of these retest specimens meet the test requirements. No further retests shall be permitted.

(*B*) *Absorption Test*

Test Specimens. 26. Absorption tests shall be made by the following method:

(*a*) The number of absorption test specimens shall be equal to the number of pipe provided for testing. The specimen shall be obtained from pipe that are acceptable as to strength and shall be taken from pipe used in making the strength test after that test is made. The specimens shall be marked with the number or identification mark of the pipe from which they were taken. Each specimen shall have an area of 16 to 24 sq. in. and a thickness equal to the full depth of the pipe shell, and shall be free from visible cracks.

Drying Specimens. (*b*) Specimens shall be dried at a temperature of approximately 110° C. (230° F.) until no loss of weight is shown by successive weighings at intervals of not less than four hours.

Immersion and Reweighing. (*c*) The dried specimens shall be placed in a suitable receptacle, covered with distilled water or rain water, raised to the boiling point and boiled for five hours, and then cooled in water to a final temperature of from 15 to 20° C. (59 to 68° F.). When cool the specimens shall be removed from the water, allowed to drain for not more than one minute, the superficial water removed by a towel or blotting paper, and the specimens immediately weighed.

Weighing Devices. (*d*) The balance used shall be sensitive to 0.5 g. when loaded with 1 kg., and weighings shall be read at least to the nearest gram. Where other than metric weights are used, the same degree of accuracy shall be obtained.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 143.

Calculation and Reporting of Results. (*e*) The increase in weight of the boiled specimen over its dry weight shall be considered the absorption of the specimen and shall be calculated as a percentage of the dry weight. The results shall be reported separately for each specimen.

Test Equipment. 27. Every manufacturer furnishing pipe under these specifications shall furnish all facilities necessary to carry out the tests required in these specifications.

SIZE AND PERMISSIBLE VARIATIONS

Standard Sizes. 28. Pipe of the internal diameters listed in the design tables shall be considered standard sizes for culvert construction. In elliptical pipe, the inside diameter at the minor axis shall be equal to the diameter of the corresponding size of circular pipe.

Variations in Dimensions. 29. (*a*) Variations of the internal diameter shall not exceed $1\frac{1}{2}$ per cent nor shall the shell thickness be less than that intended in the design by more than 5 per cent at any point.

(*b*) Variation in the position of the reinforcement cages shall not exceed $\frac{1}{4}$ in. from the position provided in the design, nor shall the cover on the reinforcement be less than $\frac{3}{4}$ in. at any point.

WORKMANSHIP AND FINISH

Finish. 30. Pipe shall be substantially free from fractures, large or deep cracks and surface roughness. The planes of the ends of the pipe shall be perpendicular to their longitudinal axes.

MARKING

Markings. 31. The following shall be clearly stenciled on the pipe:

(*a*) The pipe class $\left\{\begin{array}{l}\text{by an “S” for Standard Pipe; and}\\ \text{by an “X” for Extra-Strength Pipe;}\end{array}\right.$

(*b*) The date of manufacture;

(*c*) The name or trade-mark of the manufacturer;

(*d*) Elliptical pipe with circular reinforcing and circular pipe with elliptical reinforcing shall have the word “Top” or “Bottom” clearly stenciled on the inside of the pipe at the correct place to indicate the proper position when laid.

INSPECTION AND REJECTION

Minimum Age for Shipment. 32. Pipe shall be considered ready for shipment when they conform to the test requirements, or when tests of 6 by 12-in. cylinders (Section 24) show that the concrete has attained the strength assumed in the design of the pipe.

Inspection.

33. All materials, processes of manufacture and finished pipe shall be subject to inspection and approval by an inspector employed by the purchaser. The manufacturer, when so directed by the inspector, shall have holes cut in such sections of the finished pipe (not exceeding one hole in every 50 sections delivered) as desired so that a proper inspection may be made of the quantity and placement of the reinforcement. If the pipes are tested for strength or absorption, inspection of the reinforcement shall be made on the pipe used for those tests, and in no case shall the total number of pipe cut open for inspection or reinforcement exceed the number to which the purchaser is entitled under the provisions of Sections 21 or 22.

Causes for Rejection of Pipe.

34. Pipe shall be subject to rejection on account of failure to meet any of the specification requirements or on account of any of the following:

(*a*) Fractures or cracks passing through the shell, except that an end crack that does not exceed the depth of the joint, or a fracture that at its deepest point does not exceed the depth of the joint nor extend more than 10 per cent around the circumference shall not be considered cause for rejection unless these defects exist in more than 5 per cent of the pipe inspected;

(*b*) Defects which indicate imperfect mixing and molding;

(*c*) Exposure of the reinforcement when such exposure would indicate that the reinforcement is misplaced.

TENTATIVE SPECIFICATIONS
FOR
GLAZIER'S PUTTY[1]

A.S.T.M. Designation: D 317 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. These specifications cover two classes of putty for glazing and similar purposes, as follows:

Class A.—Whiting putty.

Class B.—White lead whiting putty.

The putty shall be furnished in natural color, or tinted or colored as specified by the purchaser.

MANUFACTURE

Process. 2. The putty shall be made by thoroughly grinding or "chasing" the specified dry pigment with pure raw linseed oil to a dough-like paste of proper consistency.

PROPERTIES AND TESTS

Pigment. 3 (*a*) The dry pigment shall conform to the following requirements:

	WHITING PUTTY	WHITE-LEAD WHITING PUTTY
Calcium Carbonate, minimum, per cent	95	..
White lead, minimum, per cent	..	10
Total calcium carbonate and white lead, minimum, per cent	..	95
Tinting pigment plus impurities, maximum, per cent	5	5

(*b*) *Whiting.*—The whiting used in both classes of putty shall be a finely-powdered natural chalk of high grade. It shall be free from grit and be practically neutral. It shall have the structure and other physical characteristics of the best natural whiting suitable for putty making.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

(*c*) *White-Lead.*—The white lead shall be pure, basic lead carbonate.

(*d*) *Tinting Pigment.*—Tinting or coloring pigments, if used, shall be pure and be used in minimum quantity to secure the specified tint or shade.

Linseed Oil. 4. The liquid shall consist entirely of pure raw linseed oil.

Finished Putty. 5. (*a*) The finished putty shall conform to the following requirements:

	Whiting Putty		White-Lead Whiting Putty	
	Maximum	Minimum	Maximum	Minimum
Pigment, per cent	87	82	87	82
Pure raw linseed oil, per cent	18	13	18	13
Moisture and other volatile matter, per cent	0.5	..	0.5	..
Alkalinity (to boiling water) calculated as calcium carbonate, per cent	0.1	..	0.1	..
Coarse particles and skins (total residue retained on a No. 325 sieve[1]) per cent of the dry pigment	3.0	..	3.0	..

(*b*) The finished putty, after working in the hands, shall have good plastic quality without sticking to the hands. It shall work readily and smoothly under a knife without crumbling or cracking. After being molded in place it shall hold its shape until set.

(*c*) Tinted or colored putty shall match, in tint or color, a sample mutually agreed upon by buyer and seller.

(*d*) The putty, as received, shall not be caked or hardened in the container.

Number of Samples. 6. One sample shall be taken at random from each lot of 10,000 lb. or fraction thereof.

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[1] For determining coarse particles and skins, sieves 3 in. in diameter are recommended, conforming to the requirements of the Standard Specifications for Sieves for Testing Purposes (A.S.T.M. Designation: E 11) of the American Society for Testing Materials, see 1930 Book of A.S.T.M. Standards, Part II, p. 1119.

TENTATIVE SPECIFICATIONS AND TESTS
FOR
SOLUBLE NITROCELLULOSE[1]

A.S.T.M. Designation: D 301 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.[2]

Scope.

1. These specifications cover the material known as soluble nitrocellulose (also known as soluble cotton), which is shipped wet to conform to the regulations of the Interstate Commerce Commission.

PROPERTIES AND TESTS

Properties and Tests.

2. (*a*) *Appearance.*—The nitrocellulose shall not be discolored and shall be free from lumps and foreign matter, such as charred particles.

(*b*) *Ash.*—The ash content shall not exceed 0.30 per cent, calculated on the basis of dry-weight soluble nitrocellulose.

(*c*) *Nitrogen.*—The percentage of nitrogen, calculated on the basis of dry-weight soluble nitrocellulose, shall be within the limits mutually agreed upon by the buyer and seller for the particular type of soluble nitrocellulose.

(*d*) *Stability.*—The stability as determined by the 134.5° C. test shall not be less than 25 minutes.

(*e*) *Consistency* (*Viscosity*).—The consistency shall be within the limits mutually agreed upon by the buyer and seller for the particular type of soluble nitrocellulose.

(*f*) *Solubility and Appearance of the Solution.*—The solubility and appearance of the sample shall be equal to the standard for the particular type of soluble nitrocellulose.

(*g*) *Film Test.*—The film test of the sample shall be equal to that of the standard for the particular type of soluble nitrocellulose.

(*h*) *Toluol Dilution Test.*—The toluol dilution value of the sample shall be equivalent to that of the standard for the particular type of soluble nitrocellulose.

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[1] Criticisms of these Tentative Specifications and Tests are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Latest revision approved by Committee E-10 on Standards, August 12, 1930.

METHOD OF SAMPLING

Sampling. 3. Samples shall be taken from not less than 10 per cent (at least two barrels) of each lot or batch in the shipment. In sampling the barrels two samples of approximately 1 pt. each shall be taken from two well separated points at least 1 ft. beneath the surface of the material in the barrel. These samples shall then be composited to represent each lot or batch in the shipment.

METHODS OF TESTING

ASH

Procedure. 4. The percentage of ash shall be determined as follows:

Weigh approximately 2 g. of the sample in a tared and ignited crucible and dry for approximately 30 minutes at 100° C. Determine the dry weight of the sample. Moisten the residue with 20 to 30 drops of c.p. nitric acid and heat on a steam bath until the sample is decomposed to a gummy mass. If necessary to complete the decomposition, add several additional drops of nitric acid at intervals. Then heat the crucible slowly over a bunsen burner or in an electric furnace until all volatile matter is driven off. Finally, ignite at red heat to constant weight, cool and weigh.

$$\text{Percentage of ash} = \frac{\text{Wt. of ash}}{\text{Wt. of dry sample}} \times 100 .$$

NOTE.—Danger from inflammable vapor may be avoided by a preliminary air drying of the sample in the event that the number of samples being tested or the construction of the oven are such as to warrant this precaution.

NITROGEN

Apparatus. 5. Use the duPont nitrometer[1] which is illustrated in Figs. 1 to 4. Figure 2 (*b*) shows the universal measuring tube, although the nitrocellulose measuring tube shown in Fig. 2 (*a*) is preferable for testing nitrocellulose. If desired, both measuring tubes may be included in the assembly, by replacing the 3-way glass manifold with a 4-way manifold.

Procedure. 6. The percentage of nitrogen shall be determined as follows:

NOTE 1.—The cellulose acetate mask must be worn during the generation and measurement of the gas as a precaution in case of an explosion.

NOTE 2.—Nitrogen-free c.p. sulfuric acid shall be used.

(*a*) Accurately calibrate the measuring tube in the usual manner, using mercury as the calibrating liquid.

(*b*) Standardize the apparatus using c.p. potassium nitrate recrystallized three times from 95 per cent ethyl alcohol, ground to pass a 100-mesh screen, and dried for 2 to 3 hours at 135 to 150° C. Fill the compensating, measuring and reaction tubes and their connections with mercury. Run 20 to 30 cc. of 94.5 ±0.5 per cent sulfuric acid (see Note 2) into the reaction bulb through the cup at the top and let in about 210 cc. of air. Close the stopcocks and shake the bulb well. This desiccates the air which is then run into the compensating tube until the mercury is about on a level with the 12.50 per cent mark on the measuring tube, the two tubes being held at the same height. Then seal the compensating tube using a small, blow-pipe flame. Accurately weigh 0.9000 to 1.0000 g. of the potassium nitrate and introduce into the reaction bulb. Wash the

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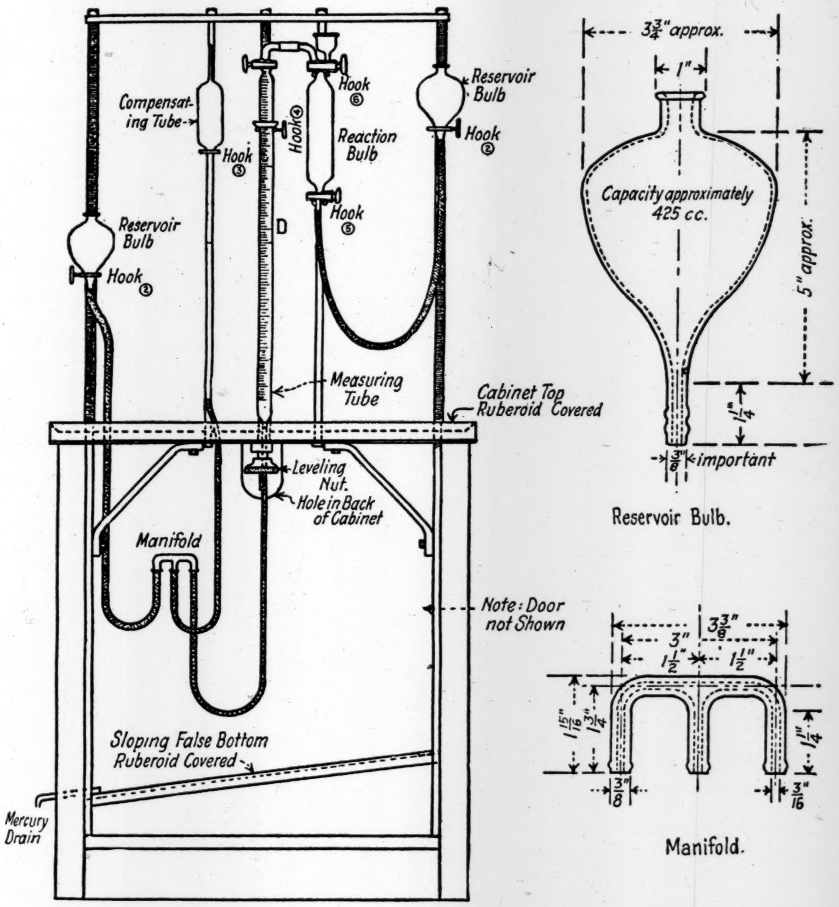
[1] Drawings reproduced by permission from the Standard Specifications for Laboratory Apparatus Adopted by the Manufacturing Chemists' Association of the United States, Part I.

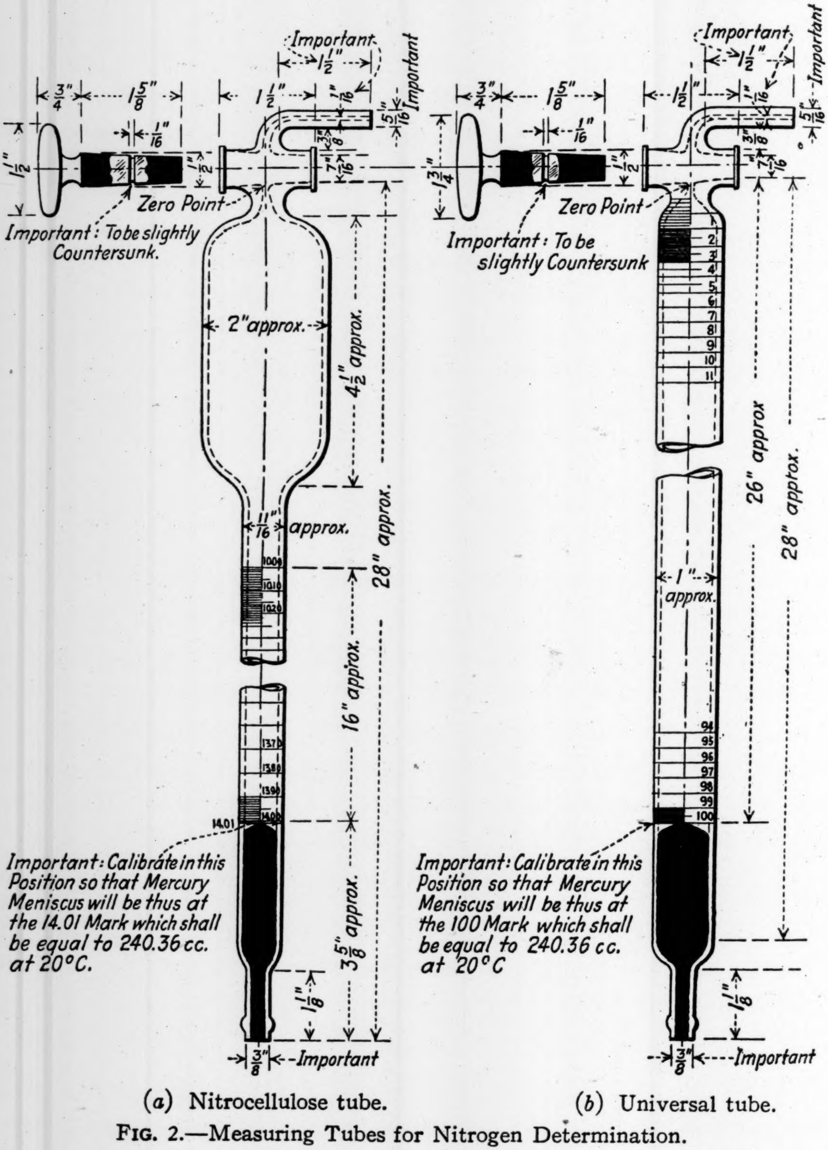

Compensating Tube
Hook ③
Hook ④
Hook ⑥
Reaction Bulb
Hook ⑤
Reservoir Bulb
Hook ②
Reservoir Bulb
Hook ①
D
Measuring Tube
Cabinet Top Ruberoid Covered
Leveling Nut.
Hole in Back of Cabinet
Manifold
Note: Door not Shown
Sloping False Bottom Ruberoid Covered
Mercury Drain
3¾" approx.
1"
Capacity approximately 425 cc.
5" approx.
1¼"
3/8" important
3 3/8"
3"
1½"
1½"
1 15/16"
1¾"
1¼"
3/8"
3/16"

Reservoir Bulb.

Manifold.

Fig. 1.—General Assembly of Apparatus for Nitrogen Determination.

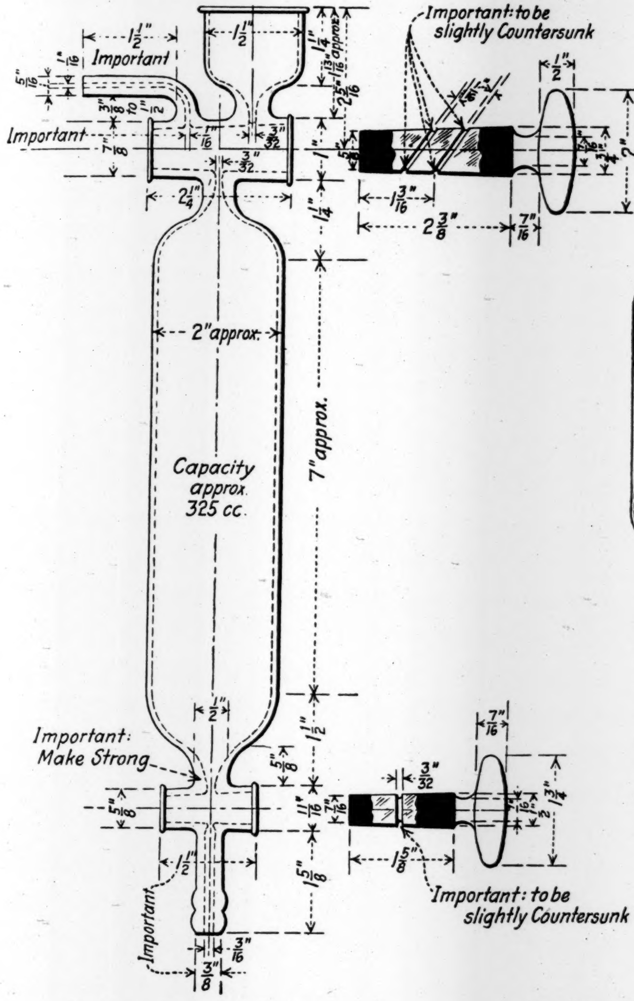
cup with 20 cc. of 94.5 ±0.5 per cent c.p. sulfuric acid (see Note 2) in three or four portions, each portion being run separately into the


Important
$1\frac{1}{2}''$
Important
$\frac{3}{4}''$
$1\frac{5}{8}''$
$1\frac{1}{2}''$
$\frac{1}{16}''$
$\frac{5}{16}''$
$\frac{1}{16}''$
$\frac{1}{2}''$
$\frac{1}{2}''$
$\frac{3}{8}''$
$\frac{7}{16}''$
Zero Point
Important: To be slightly Countersunk.
2" approx.
$4\frac{1}{2}''$ approx.
$\frac{11}{16}''$ approx.
28" approx.
1000
1010
1020
16" approx.
1370
1380
1390
1400
14.01
Important: Calibrate in this Position so that Mercury Meniscus will be thus at the 14.01 Mark which shall be equal to 240.36 cc. at 20°C.
$3\frac{5}{8}''$ approx.
$1\frac{1}{8}''$
$\frac{3}{8}''$
Important
Important
$1\frac{1}{2}''$
Important
$\frac{3}{4}''$
$1\frac{5}{8}''$
$1\frac{1}{2}''$
$\frac{1}{16}''$
$\frac{5}{16}''$
$\frac{1}{16}''$
$1\frac{3}{4}''$
$\frac{1}{2}''$
$\frac{3}{8}''$
$\frac{7}{16}''$
Zero Point
Important: To be slightly Countersunk
2
3
4
5
6
7
8
9
10
11
26" approx
28" approx.
1" approx.
94
95
96
97
98
99
100
Important: Calibrate in this Position so that Mercury Meniscus will be thus at the 100 Mark which shall be equal to 240.36 cc. at 20°C
$1\frac{1}{8}''$
$\frac{3}{8}''$
Important

(*a*) Nitrocellulose tube. (*b*) Universal tube.

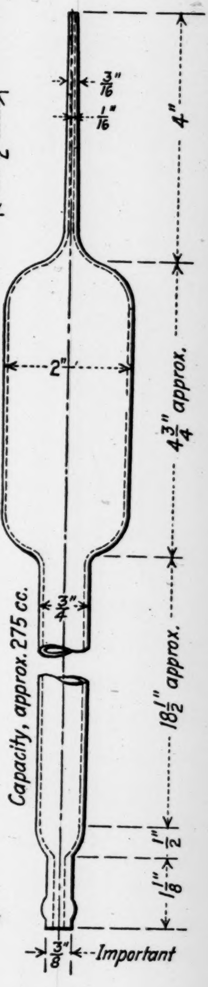
FIG. 2.—Measuring Tubes for Nitrogen Determination.

bulb. During this operation allow the bottom stopcock of the reaction bulb to remain open. Then with the bottom stopcock still open lower the reservoir bulb to give reduced pressure in the reaction bulb and gently shake the reaction bulb to start the decomposition. After the evolution of NO has become slow (it is extremely important that the bottom stopcock be left open until the major part of the decomposition has occurred; otherwise sudden evolution of gas will burst the bulb scattering acid and glass) lower the reservoir bulb until all but 25 cc. of the mercury in the reaction bulb is withdrawn, close the bottom stopcock and shake the reaction bulb vigorously for 5 minutes. When the reaction is completed allow the gas to cool



1 1/2"
Important
Important
1 1/2"
2 1/4"
Important: to be slightly Countersunk
2 3/8"
1 3/16"
7/16"
1/2"
2"
2" approx.
Capacity approx. 325 cc.
7" approx.
Important: Make Strong
1/2"
1 1/2"
3/32"
7/16"
1 3/4"
1 5/8"
1 5/8"
Important: to be slightly Countersunk
Important
1 1/2"
3/16"
3/8"

Fig. 3.—Reaction Bulb.



3/16"
1/16"
4"
2"
4 3/4" approx.
3/4"
Capacity, approx. 275 cc.
18 1/2" approx.
1 1/2"
1 1/8"
3/8"
Important

Fig. 4.—Compensating Tube.

for 20 minutes, then transfer the gas to the measuring tube. By means of the leveling device make careful adjustment of the mercury levels so that the mercury in the measuring tube is at the 13.85-per-cent mark (the theoretical percentage of nitrogen in potassium nitrate) if exactly a 1.0000-g. sample was used or a proportional reading if less was used. Paste a strip of paper on the compensating tube at the level of the mercury and the standardization is completed. It is advisable to make several check determinations, preferably on different days, to insure accurate standardization. Determinations should check within ±0.01 per cent.

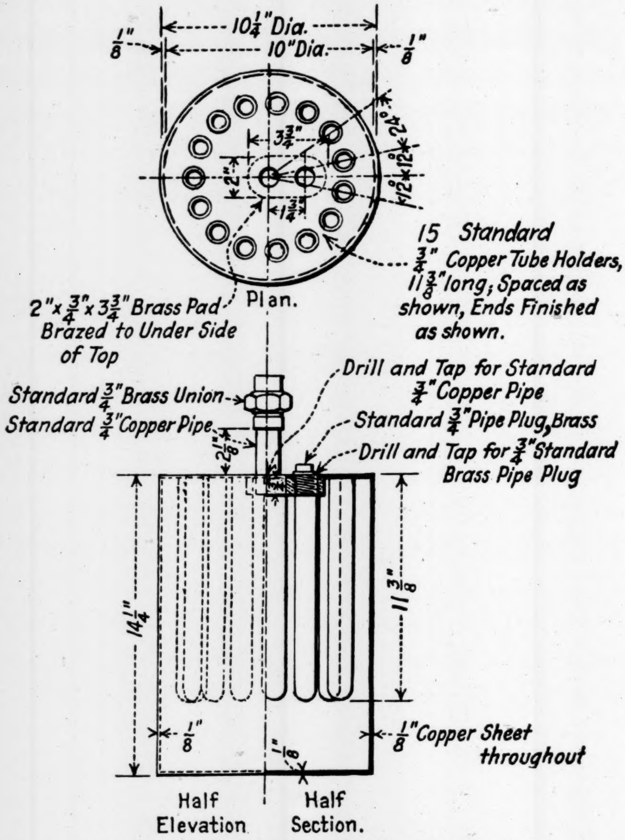

1/8"
10 1/4" Dia.
10" Dia.
1/8"
3 3/4"
2"
1 3/4"
24°
12°
12°
12°
15 Standard 3/4" Copper Tube Holders, 11 3/8" long; Spaced as shown, Ends Finished as shown.
2"x 3/4"x 3 3/4" Brass Pad Brazed to Under Side of Top
Plan.
Drill and Tap for Standard 3/4" Copper Pipe
Standard 3/4" Brass Union
Standard 3/4" Copper Pipe
Standard 3/4" Pipe Plug, Brass
Drill and Tap for 3/4" Standard Brass Pipe Plug
2 5/8"
14 1/4"
11 3/8"
1/8"
1/8"
1/8" Copper Sheet throughout
Half Elevation
Half Section.

FIG. 5.—Copper Bath for Stability Test.

(*c*) Roughly dry the soluble nitrocellulose as for the ash determination described in Section 4 and weigh a sample of from 1.0 to 1.5 g. in a weighing bottle. Dry to constant weight at 98 to 102° C.

(1 to 1½ hours usually suffices) and cool in a desiccator. Transfer to the cup of the reaction bulb of the nitrometer; then, using 94.5 ±0.5-per-cent c.p. sulfuric acid dissolve the sample, withdraw into the reaction bulb and rinse the cup into the bulb several times. Use a total of 20 cc. of acid for dissolving and rinsing. Complete the determination in accordance with the standardization of the apparatus described in Paragraph (*b*) and take a reading after adjusting the level of the mercury in the reading tube to the mark on the compensating tube. The reading divided by the weight of sample gives the percentage of nitrogen.

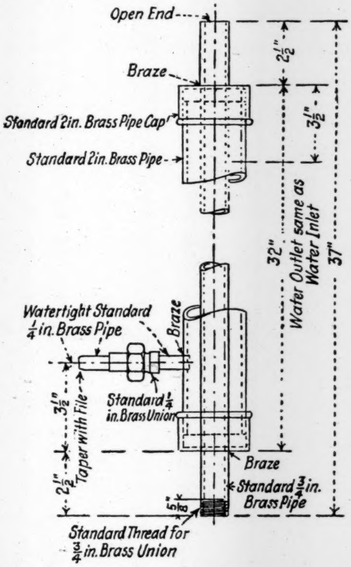

Open End
Braze
2½"
Standard 2in. Brass Pipe Cap
3½"
Standard 2in. Brass Pipe
32"
Water Outlet same as Water Inlet
37"
Watertight Standard ¼ in. Brass Pipe
Braze
3½"
Taper with File
Standard ¼ in. Brass Union
2½"
Braze
Standard ¾ in. Brass Pipe
5/8"
Standard Thread for ¾ in. Brass Union

FIG. 6.—Brass Condenser for Stability Test Apparatus.

STABILITY

Apparatus

7. The apparatus shall consist of the following:

(*a*) *Copper Bath.*—Copper bath with copper or brass condenser, as shown in Figs. 5 and 6. These baths are usually made to hold 13 or 15 test tubes.

(*b*) *Test Tubes.*—Fifteen Pyrex glass test tubes 290 mm. ± 1 mm. in length with an outside diameter of 18 mm. and a wall thickness of 1.5 mm.

(*c*) *Heater.*—An electric hot plate for heating the bath.

(*d*) *Face Mask.*—A face mask, so constructed that a heavy piece of clear cellulose-acetate celluloid sheeting protects the face.

(*e*) *Gloves.*—A pair of heavy gloves.

(*f*) *Pincers.*—Long pincers for handling the test tubes.

(*g*) *Thermometer.*—A mercury-filled thermometer graduated in centigrade degrees, the range being 130 to 140° C. in 0.1° C. Diameter, $\frac{5}{16}$ in. ± $\frac{1}{16}$ in.; over-all length, 18 in. ± $\frac{1}{4}$ in.; length of bulb, $2\frac{3}{8}$ in. ± $\frac{1}{4}$ in.; distance from bulb to first graduation, $8\frac{5}{8}$ in. ± $\frac{1}{4}$ in.; distance from lowest graduation to highest graduation, $4\frac{3}{4}$ in. ± $\frac{1}{4}$ in. Solid stem, white enamel back. Graduations to be numbered at 130, 135 and 140° C. The first and each succeeding 0.5° C. line to be longer than the remaining lines. All graduation lines and figures to be etched on the stem clear cut and distinct. Reservoir at the top to accommodate expansion up to 175° C. Accuracy to be within 0.2° C. over entire scale

Solution Required. 8. *Methyl Violet Test Paper.*—Conduct the preparation and drying of the methyl violet test paper in a room that is free of acid fumes. Prepare a dye solution according to the following formula:

Pararosaniline[a] (converted to acetate)	0.2500 g.
Crystal violet	0.1680 g.
C.p. glycerin	6 cc.
Distilled water	30 cc.
95-per-cent ethyl alcohol	sufficient to make-up to 100 cc.

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[a] The pararosaniline acetate used in the foregoing formula is made by adding an excess of glacial acetic acid to 0.2500 g. of pararosaniline and heating in a porcelain casserole over a steam bath until the excess acid is removed. The other ingredients are then added and volume made up to a total of 100 cc. with 95-per-cent ethyl alcohol. The crystal violet mentioned in the formula may be replaced by Methyl Violet N.E. (E.I. duPont de Nemours and Co.) or Methyl Violet 2 B (National Aniline and Chemical Co.)

Place a small quantity of the dye solution into a rectangular glass tray that is supported in a tilted position. Slowly draw a quarter sheet of filter paper through the solution and up and over the side of the dish to remove the excess liquid. The filter paper shall be carefully selected and of such properties as to maintain a permanent color when treated. The S and S No. 597 filter paper has been found to be the only paper giving consistent results. Holding the sheet horizontally, wave it gently back and forth for about one minute, then suspend vertically until dry. When dry, cut into strips 70 by 20 mm. and store in a well-stoppered bottle.

Check each batch of prepared test papers against the papers held as standard by testing the same sample of nitrocellulose with both papers.

Procedure. 9. Stability shall be determined by the 134.5° C. stability test, as follows:

Conduct the test in a room that is free of acid fumes. Dried nitrocellulose is very inflammable and if ignited by fire, spark or static electricity will flare up and shatter the test tube. It is important, therefore, that the operator wear the cellulose acetate mask and heavy gloves and that the tubes be handled with long pincers.

Maintain the heating bath at a temperature of 134.5° C. ±0.5° C. by the use of the required mixture of toluol and xylol. The proper mixture is approximately one part xylol and four parts toluol, but the exact proportions must be determined by the "cut-and-try" method. If the mixture started with is too high, add more toluol; if it is too low, allow the condenser to run hot until the desired temperature is reached. On continued operation the tendency is for the temperature to rise, which should be corrected by adding toluol.

Weigh accurately 2.5 g. of the sample previously dried for 4 to 5 hours at 40 to 45° C. or air dried over night followed by a drying for 30 minutes at 40 to 45° C. Shake or press the sample down in the test tube so that it occupies the lower two inches of the tube and swab out all nitrocellulose particles, adhering to the inside wall of the tube. Place the methyl violet test paper in the tube so that its lower edge is 1 in. from the top of the sample in which position the paper must remain throughout the test. Stopper the tube with a cork provided with a hole or notch 4 mm. in diameter to allow for expansion and contraction of the air in the tube. Place the tube containing the sample in the heating bath maintained at a temperature of 134.5° C. ±0.5° C. The tube must project not less than 5 nor more than 7 mm. above the top of the bath. Beginning at the end of the first twenty minutes, inspect the tube at 5-minute intervals by lifting the tube until the methyl violet paper, but not the soluble nitrocellulose, is visible above the surface of the bath. The end point is reached when the test paper completely loses its violet color. For example, if the color is not completely changed in 20 minutes but is completely changed in 25 minutes the stability of the sample is recorded as 25 minutes.

CONSISTENCY, FILM AND TOLUOL DILUTION TESTS

SOLUTIONS REQUIRED

Solutions Required.

10. The solutions used shall conform to the following formulas:

	FORMULA A	FORMULA B	FORMULA C	FORMULA D
Soluble nitrocellulose (dried at 50° C. to constant weight), per cent by weight	12.2	20.0	25.0	12.2
Ethyl acetate,[a] per cent by weight	17.5	16.0	15.0	....
Denatured alcohol, commercially distilled (No. 1, 188-proof) per cent by weight	22.0	20.0	18.75	....
Toluol,[b] per cent by weight	48.3	44.0	41.25	....
Normal butyl acetate,[c] per cent by weight	....	....	....	87.8

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[a] Ethyl acetate conforming to the requirements of the Tentative Specifications for Ethyl Acetate (85 to 88 per cent Grade) (A.S.T.M. Designation: D 302 - 30 T) of the American Society for Testing Materials.[1]

[b] Non-corrosive toluol, 2° C. boiling range, including the boiling point of toluene, 110.7° C.

[c] Normal butyl acetate conforming to the requirements of the Tentative Specifications for Normal Butyl Acetate (88 to 92 per cent Grade) (A.S.T.M. Designation: D 303 - 30 T) of the American Society for Testing Materials.[2]

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[1] See p. 1080.

[2] See p. 1082.

CONSISTENCY

Apparatus.

11. (*a*) *Cylinder.*—A glass cylinder 1.0 in. ±0.02 in. (25.4 mm. ±0.5 mm.) in inside diameter, 14 in. in height, and with marks 10.0 in. ±0.10 in. (254.00 mm. ±0.25 mm.) on the side at points about 2 and 12 in. from the top.

(*b*) *Steel Ball.*—A steel ball 0.3120 to 0.3130 in. (0.794 cm. ±0.001 cm.) in diameter and weighing 2.035 g. ±0.010 g.

Procedure.

12. (*a*) *Consistency (Viscosity).*—Consistency is determined by putting the soluble nitrocellulose in solution using a standard formula and noting the rate at which a standard steel ball drops through the solution.

Formula A, B or C is usually used for determining consistency. Use Formula A unless the sample gives a viscosity with it of 6 seconds or less, in which case use Formula B, if below 3 seconds in Formula B use Formula C. The solution of the nitro-cellulose will be completed somewhat more quickly if the alcohol and toluol be added first and the mixture be then allowed to stand 5 or 10 minutes before the ethyl acetate is added. Completely dissolve the sample in the solvent mixture by agitating in a tightly-closed container. Fill the glass cylinder with this solution. Stopper the cylinder, allow to stand until all air bubbles have passed out of the solution and bring to a temperature of 25.0° C. ±0.1° C. Place the cylinder in a vertical position and release the steel ball at the center of the upper surface of the solution and allow it to fall through the solution. The number of seconds required for the ball to pass through the 10-in. column of solution between the 2 and 12-in. marks on the cylinder, is recorded as the consistency of the sample.

(*b*) *Report.*—In reporting the consistency prefix the letter A, B or C to the value of the consistency determined in Paragraph (*a*) in order to indicate the solution formula used.

Solubility and Appearance.

13. *Solubility and Appearance of the Solution.*—Compare either Formula A, B, C or D (Note) with a freshly-prepared standard solution of the same type of soluble nitrocellulose of the same formula. Make the comparison in small vials and note the color, turbidity, "grain," and "flock."

NOTE.—Formula A, B or C which was prepared for the consistency determination is ordinarily used. When the soluble nitrocellulose is to be used for purposes requiring extreme transparency and clarity, use Formula D.

FILM TEST

Film Test.

14. Dilute Formula A, B or C with an equal volume of normal butyl acetate and pour the solution beside a freshly-prepared standard

solution, of the same type of soluble nitrocellulose, of the same formula, on a clean glass plate. Allow to dry in a nearly vertical position in a dust-free atmosphere. Compare the sample with the standard for undissolved particles, which indicate un-nitrated cotton or impurities, and for poor flow and poor gloss.

TOLUOL DILUTION TEST

Toluol Dilution Test.

15. To 50 cc. of Formula D in a stoppered bottle, add c.p. toluol (Note) in small quantities from a burette, shaking well after each addition. The first permanent separation of soluble nitrocellulose is taken as the dilution value and is expressed as a percentage by volume of Formula D.

NOTE.—Large quantities of butyl acetate and toluol should be reserved for this test to avoid possible variation between different lots.

TENTATIVE SPECIFICATIONS
FOR
AMYL ACETATE (SYNTHETIC)[1]

A.S.T.M. Designation: D 318 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1930.

Properties. 1. Amyl acetate (synthetic) shall conform to the following requirements:

Specific gravity 20°/20° C.	0.860 to 0.870
Color	water white
Distillation range:[a]	
Below 126° C.	none
Below 130° C.	not more than 5 per cent
Below 135° C.	not more than 25 per cent
Below 140° C.	not more than 75 per cent
Above 155° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity in all proportions with 60° Baumé gasoline at 20° C.
Acidity (free acid as acetic acid)	not more than 0.03 per cent, equivalent to 0.28 mg. KOH per gram of sample
Ester value	85 to 88 per cent by weight

[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, –5 to +300° C., +20 to +580° F. (A.S.T.M. Designation: D 183) of the American Society for Testing Materials.[2]

Methods of Testing. 2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1115.

[3] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
AMYL ALCOHOL (SYNTHETIC)[1]

A.S.T.M. Designation: D 319 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930; REVISED, 1930.[2]

Properties.

1. Amyl alcohol (synthetic) shall conform to the following requirements:

Purity	consists of a mixture of the various isomeric forms of amyl alcohol and contains at least 98 per cent of these alcohols
Specific gravity 20°/20° C.	0.812 to 0.820
Color	water white
Distillation range:[a]	
Below 118° C.	none
Below 120° C.	not more than 5 per cent
Below 125° C.	not more than 50 per cent
Below 130° C.	not more than 85 per cent
Above 140° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity with 19 volumes of 60° Baumé gasoline at 20° C.
Acidity (free acid as acetic acid)	none

[a] The therometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.[3]

Methods of Testing.

2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[4]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Revision approved by Committee E-10 on Standards, August 12, 1930.

[3] 1930 Book of A.S.T.M. Standards, Part II, p. 1113.

[4] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
ETHYL ACETATE (85 TO 88 PER CENT GRADE)[1]

A.S.T.M. Designation: D 302 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

Properties. 1. Ethyl acetate shall conform to the following requirements:

Specific gravity, 20°/20° C.	0.883 to 0.888
Color	water white
Distillation range:[a]	
Below 70° C.	none
Below 72° C.	not more than 10 per cent
Above 80° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity with ten volumes of 60° Baumé gasoline at 20° C.
Acidity (free acid as acetic acid)	not more than 0.02 per cent, equivalent to 0.19 mg. KOH per gram of sample
Ester value	85 to 88 per cent by weight

[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.[2]

Methods of Testing. 2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1113.

[3] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
ETHYL LACTATE (SYNTHETIC)[1]

A.S.T.M. Designation: D 321 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Properties.

1. Ethyl lactate (synthetic) shall conform to the following requirements:

Specific gravity 20°/20° C.	1.020 to 1.036
Color	water white
Distillation range:[a]	
Below 102° C.	none
Below 139° C.	not more than 10 per cent
Below 155° C.	not less than 90 per cent
Above 173° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity in all proportions with 60° Baumé gasoline at 20° C.
Acidity (free acid as lactic acid)	not more than 0.08 per cent, equivalent to 0.5 mg. KOH per gram of sample
Ester value	96 to 100 per cent by weight

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[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, –5 to +300° C., +20 to +580° F. (A.S.T.M. Designation: D 183) of the American Society for Testing Materials.[2]

Methods of Testing.

2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1115.

[3] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
NORMAL BUTYL ACETATE (88 TO 92 PER CENT GRADE)[1]

A.S.T.M. Designation: D 303 – 30 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

Properties. 1. Normal butyl acetate shall conform to the following requirements:

Specific gravity, 20°/20° C.	0.872 to 0.878
Color	water white
Distillation range:[a]	
Below 110° C.	none
Below 120° C.	not more than 15 per cent
Above 127° C.	not more than 30 per cent
Above 145° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity in all proportions with 60° Baumé gasoline at 20° C.
Acidity (free acid as acetic acid)	not more than 0.03 per cent, equivalent to 0.28 mg. KOH per gram of sample
Ester value	88 to 92 per cent by weight

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[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.[2]

Methods of Testing. 2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1113.

[3] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
BUTANOL (NORMAL BUTYL ALCOHOL)[1]

A.S.T.M. Designation: D 304 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

Properties.

1. Butanol (normal butyl alcohol) shall conform to the following requirements:

Purity	to contain not less than 98 per cent of normal butyl alcohol
Specfic gravity, 20°/20° C.	0.810 to 0.815
Color	water white
Distillation range;[a]	
Below 100° C.	none
Below 105° C.	not more than 2 per cent
Below 115° C.	not more than 10 per cent
Above 118° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	no cloud when one volume of Butanol is mixed with 19 volumes of 60° Baumé gasoline at 20° C.
Acidity (free acid as acetic acid)	not more than 0.03 per cent, equivalent to 0.28 mg. KOH per gram of sample.

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[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150° C., 0 to +300° F. (A.S.T.M. Designation: D 182) of the American Society for Testing Materials.[2]

Methods of Testing.

2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1113.

[3] See p. 1085.

TENTATIVE SPECIFICATIONS
FOR
BUTYL PROPIONATE (90 TO 93 PER CENT GRADE)[1]

A.S.T.M. Designation: D 320 – 30 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Properties. 1. Butyl propionate (90 to 93-per-cent Grade) shall conform to the following requirements:

Specific gravity 20°/20° C.	0.872 to 0.878
Color	water white
Distillation range:[a]	
Below 115° C.	none
Below 130° C.	not more than 20 per cent
Below 138° C.	not more than 60 per cent
Above 168° C.	none
Non-volatile matter	not more than 0.005 g.
Odor	mild, non-residual
Water	miscible without turbidity in all proportions with 60° Baumé gasoline at 20° C.
Acidity (free acid as propionic acid)	not more than 0.02 per cent, equivalent to 0.15 mg. KOH per gram of sample
Ester value	90 to 93 per cent by weight.

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[a] The thermometer used for the distillation test shall conform to the requirements of the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, –5 to +300° C., +20 to +580° F. (A.S.T.M. Designation: D 183) of the American Society for Testing Materials.[2]

Methods of Testing. 2. The sampling and methods of testing shall be conducted in accordance with the Tentative Methods of Sampling and Testing Lacquer Solvents and Diluents (A.S.T.M. Designation: D 268 – 30 T) of the American Society for Testing Materials.[3]

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1115.

[3] See p. 1085.

TENTATIVE METHODS OF SAMPLING AND TESTING LACQUER SOLVENTS AND DILUENTS[1]

A.S.T.M. Designation: D 268 – 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1927: REVISED, 1929, 1930.[2]

Scope. 1. These methods cover the sampling and tests to be applied to solvents and diluents for use in the manufacture of nitro-cellulose lacquer.

SAMPLING

Sampling. 2. (*a*) The method of sampling specified in Paragraph (*b*) or (*c*) shall be used, according to the special conditions that obtain.

(*b*) *From Loaded Tank Car or Other Large Vessel.*—The composite sample taken shall not be less than ½ gal. and should consist of small samples of not more than 1 qt. each, taken from near the top and bottom by means of a metal or glass container with removable stopper or top. This device, attached to a suitable pole, shall be lowered to the desired depth, when the stopper or top shall be removed and the container allowed to fill.

(*c*) *Barrels and Drums.*—At least 5 per cent of the packages in any shipment shall be represented in the sample. The purchaser may increase the percentage of packages to be sampled at his discretion, and it is recommended that every package be sampled in the case of expensive solvents that are bought in small quantity. A portion shall be withdrawn from about the center of each package sampled by means of a "thief" or other sampling device. The composite sample thus obtained shall not be less than 1 qt. and shall consist of equal portions of not less than ½ pt. from each package sampled.

METHODS OF TESTING

Specific Gravity. 3. The specific gravity shall be determined by any convenient method that is accurate to the third decimal point, the temperature of both sample and water being 20° C.

Color. 4. The sample and the standard mutually agreed upon by the buyer and seller shall be compared in 100-ml. Nessler tubes having colorless bottoms and the sides of which are covered with opaque paper for the purpose of eliminating sidelight.[1] The tubes should be filled to a height of approximately 24.5 cm., and shall be viewed from a point directly above the tube, using a white background beneath the bottom of the tube. For a solvent to be rated water-white, the visible color shall not be darker than a solution of 0.0030 g. of potassium bichromate in one liter of water when tested in the above manner.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] Latest revision approved by Committee E-10 on Standards, August 12, 1930.

Distillation.

5. The distillation test shall be conducted in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials,[2] with the following exceptions:

(*a*) The temperature of the end point of the distillation, which shall be termed the "dry point," is the temperature observed on the distillation thermometer when the last drop of liquid leaves the bottom of the distillation flask. The thermometer used shall conform to the requirements of either the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −20 to +150 °C., 0 to +300° F. (A.S.T.M. Designation: D 182)[3] or the Standard Specifications for A.S.T.M. Partial-Immersion Thermometer for General Use, −5 to +300° C., +20 to +580° F. (A.S.T.M. Designation: D 183)[4] of the American Society for Testing Materials, as specified.

(*b*) Observations of volumes of distillate shall be made at the temperature specified for the individual solvent or diluent under test.

Non-Volatile Matter.

6. Non-volatile matter of solvents and diluents shall be determined as follows:

One hundred milliliters of the sample shall be placed in a weighed porcelain evaporating dish and evaporated almost to dryness on a steam bath. It shall then be heated in an oven at 100 to 110° C. to constant weight. The increase in the weight of the dish is the non-volatile matter of the sample, which should be expressed as a percentage, calculating the weight of the sample from its specific gravity, determined as described in Section 3.

Residual Odor.

7. Residual odor shall be determined for all solvents and diluents in which residual odor is an important property. Strips of heavy filter paper, of the same size and shape, shall be dipped to the same depth in beakers or wide-mouthed bottles containing the sample and the standard. The filter papers shall be allowed to dry in air at room

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[1] Tubes conforming to these requirements may be obtained from the New Jersey Laboratory Supply Co., Newark, N. J., their Catalog No. 22565.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 491.

[3] *Ibid*, p. 1113.

[4] *Ibid*, p. 1115.

temperature and shall be examined at suitable intervals for difference in odor.

Water. 8. Five milliliters of the sample shall be transferred to a 100-ml. glass-stoppered cylinder, and 60° Baumé gasoline added in 5-ml. portions, shaking well after each addition. Both sample and gasoline shall be at a temperature of 20° C. when used. Water is indicated by turbidity. If turbidity develops, the standard shall be tested in the same way and compared.

Acidity. 9. Using a pipette, 50 ml. of the sample shall be transferred to a small Erlenmeyer flask and titrated with $0.1N$ KOH in 99-per-cent methyl alcohol, using phenolphthalein as an indicator. The weight of the sample shall be determined from the specific gravity and the acidity reported as percentage by weight of the appropriate acid, or as milligrams of KOH per gram of sample.

Alkalinity. 10. Alkalinity of solvents and diluents shall be determined only when indicated by the results obtained in Section 9. Using a pipette, 50 ml. of the sample shall be transferred to a small Erlenmeyer flask and titrated with $0.1N$ H_2SO_4, using methyl orange as an indicator. The weight of the sample shall be determined from its specific gravity and the alkalinity reported as milligrams of KOH per gram of sample.

Ester Value. 11. (*a*) One to two grams of the sample shall be weighed in an ampoule, by first weighing the empty ampoule, warming and filling, and then sealing-off and reweighing, The ampoule shall be placed in a 200-ml. Erlenmeyer flask which contains approximately one and one-half times the theoretical quantity of $0.5N$ KOH required for complete saponification. The ampoule should be broken with a stirring rod and the flask connected with a reflux condenser. The flask shall then be heated on a steam bath for one to four hours, depending upon the ester being tested. During the heating the set-up and contents should be shaken frequently, taking the usual precautions to lose none of the contents. After the apparatus has cooled, the condenser shall be washed down with distilled water and three drops of phenolphthalein added to the contents of the flask as an indicator. The contents of the flask shall be titrated with $0.5N$ HCl. Two blanks with alcoholic KOH shall be run along with the sample. These blanks should check to the first decimal point. The result shall be reported as percentage of ester by weight, allowing in the calculations for acidity or alkalinity as determined in Sections 9 and 10.

(*b*) *Optional Method.*—One to two grams of the sample shall be weighed in an ampoule by first weighing the empty ampoule, warming and filling, and then sealing off and reweighing (Note). The ampoule shall be placed in a pressure bottle of approximately 325-ml. capacity (the spring top magnesium-citrate bottle is satisfactory) which contains one and one-half times the theoretical quantity of 0.5*N* KOH required for complete saponification. The ampoule may be broken with a glass rod, subsequently washing the liquid adhering to the rod back into the bottle. After thorough agitation the bottle and contents shall be heated on a steam bath for 1 to 4 hours, depending upon the ester being tested. After the proper heating, the bottle shall be allowed to cool, then opened and the under side of the stopper and the sides of the neck washed down with distilled water. Three drops of the phenolphthalein solution shall be added to the contents of the flask as an indicator. The contents of the flask shall be titrated therein with 0.5*N* HCl. Two blanks with alcoholic KOH shall be run along with the sample. These blanks should check, on titration, to the first decimal point. The result should be reported as percentage of ester by weight, making allowance in the calculations for acidity or alkalinity as determined in Sections 9 and 10.

NOTE.—An optional method of weighing the sample is in a small weighing bottle, removing the stopper, by means of a glass rod after introduction into the pressure bottle, or by agitating the contents of the pressure bottle.

Copper Corrosion Test.

Apparatus.

12. The apparatus for the copper corrosion test shall consist of the following:

(*a*) *Pyrex Flask.*—A 300-ml. Pyrex flask with flat bottom and vial mouth.

(*b*) *Glass Condenser.*—A 12-in. glass condenser with the diameter of the condenser tube not less than $\frac{3}{8}$ in. A cork stopper to connect the flask with the condenser.

(*c*) *Copper Strip.*—A copper strip $2\frac{1}{2}$ in. by $\frac{1}{4}$ in. made from No. 20 B. & S. gage, cold-rolled, polished copper, approximate thickness 0.032 in. and having a $\frac{1}{16}$-in. hole, $\frac{1}{8}$ in. from one end. A piece of soft copper wire about 6 in. in length.

(*d*) *Water Bath.*—A water bath of convenient size and design.

Procedure.

13. The copper corrosion test shall be made as follows:

Both sides of the entire copper strip, edges excepted, shall be polished with a No. 00 emery cloth and used immediately to avoid discoloration by the atmosphere. A 6-in. length of soft copper wire shall be fastened through the hole provided near one end of the strip, care being taken not to touch the strip with the fingers after polishing. The strip shall be placed in the flask and 200 ml. of the material to be tested shall be added. The material must not contain separated water and shall be filtered through filter paper if necessary to remove water. The flask shall be connected to the vertical reflux condenser by means of a properly bored cork stopper. It is absolutely necessary that cork and not rubber stoppers be used, in order to avoid contamination of the material by sulfur from rubber stoppers. The copper wire may be allowed to extend into the condenser tube for convenience in removing the strip. The strip shall be completely immersed and should preferably lie flat and touch the flask only at the ends of the strip. The flask shall be placed in the water bath which should be just gently boiling and the flask immersed to the liquid line of the material within the flask. The copper strip shall be removed 30 minutes from the time the flask was immersed in the bath. Care should be taken not to touch the copper strip but to remove it by the wire which has been provided. The strip shall not be allowed to come in contact with separated water during any part of the test due to the fact that water causes bad local staining of the copper. If it is desired to preserve the strip for future reference it should be dipped immediately in white shellac or lacquer. The sheared edges of the test strip shall not be used as a basis for judgment; flat surfaces only shall be considered

TENTATIVE METHODS OF SAMPLING PETROLEUM AND PETROLEUM PRODUCTS[1]

A.S.T.M. Designation: D 270 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1927; Revised, 1930.

PURPOSE AND SCOPE

Purpose. 1. Samples are taken for the purpose of having representative quantities, of economical and convenient size, from a section, or from the whole of a lot of material, for examination and test, so that an agreement may be reached in regard to the following:

(*a*) The extent of variation of qualities in different portions of the lot;

(*b*) The average quality of the whole lot of material.

Scope. 2. These methods of sampling are for use in obtaining representative portions of stocks or shipments of petroleum and all petroleum products, except gases.

GENERAL CONSIDERATIONS

Personnel. 3. No set of directions for sampling, however explicit, can take the place of judgment, skill and previous experience on the part of the persons actually engaged in the sampling and in the supervision of the sampling. These directions are intended to supplement this experience and particularly to serve as a guide in the selection of the method which is to be used in common by each of two or more contracting parties.

Grades of Material. 4. The materials sampled may be graded as follows:

(*a*) Crude or unrefined materials, such as petroleum from wells, pipe lines, and tanks.

(*b*) Semi-refined materials, such as fuel oil, and gas oil.

(*c*) Refined products, such as gasoline, lubricating oils, and insulating oils.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

Classes of Material.

5. For sampling purposes, material may be classified as follows:

(*a*) Liquid materials, such as light crude oils, gas oils, lubricating oils, and naphthas.

(*b*) Semi-liquid and highly viscous materials, such as cylinder stocks, and heavy fuel oils.

(*c*) Soft solid and semi-solid materials, such as asphalts, waxes, petrolatum, and greases.

(*d*) Lumpy solid materials, such as petroleum coke.

Types of Containers.

6. These methods apply to material in the following types of containers:

(*a*) Cans or small containers (up to 10 U. S. gal., inclusive);
(*b*) Drums or barrels;
(*c*) Tank cars or tank trucks;
(*d*) Shore tanks;
(*e*) Ship tanks or barge tanks;
(*f*) Pipe lines;
(*g*) Bags;
(*h*) Cakes;
(*i*) Bulk or loose form.

Character of Tests.

7. Samples are taken for the following types of tests:
(*a*) General quality tests.
(*b*) Definite chemical and physical tests.
(*c*) Special quality tests.

Disposition of Samples.

8. Samples are used for one or more of the following purposes:
(*a*) Visual examination.
(*b*) Laboratory test.
(*c*) Preservation for record.
(*d*) Check and referee tests.

Marking Samples.

9. Samples should be marked, recorded, and handled throughout in accordance with all the usual precautions of the best laboratory technique.

DEFINITIONS

Average Sample.

10. *Average Sample.*[1]—An average sample would be one so taken as to contain parts from all sections of the container or pipe in proportion to the volume of each part.

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[1] It is practically impossible to obtain an average sample, except, perhaps, through a continuous sampling connection from a vertical run in a pipe line with specially constructed draw-off pipes, or by vigorously agitating and stirring the contents of a vessel and drawing off a sample while the contents are still agitated. Samples obtained by lowering and raising a bottle while allowing it to fill have been considered average samples, but obviously the proportions are not related to the tank volumes at the various levels.

All-Levels Sample.

11. *All-Levels Sample.*[1]—An all-levels sample is one obtained by submerging a closed sample container to a point as near as possible to the draw-off level, opening it and raising it at such a rate that it will be nearly but not quite full when withdrawn.

Upper Sample.

12. *Upper Sample.*—An upper sample is one taken at a point 10 per cent of the depth of a uniform cross-section vessel or 10 per cent of the diameter of a horizontal cylindrical tank below the surface.

Middle Sample.

13. *Middle Sample.*—A middle sample is one taken at half the depth of the material.

Lower Sample.

14. *Lower Sample.*—A lower sample is one taken at a point 10 per cent of the depth of a uniform cross-section vessel or 10 per cent of the diameter of a horizontal cylindrical tank above the bottom of the vessel.

Composite Sample.

15. (*a*) *Composite Sample.*—A composite sample is a mixture of upper, middle and lower samples containing, for vessels of different shapes, volume proportions which correspond approximately to the volumes of the material at these levels, as follows:

	COMPOSITE SAMPLE PROPORTIONS	
	UNIFORM CROSS-SECTION VESSELS	HORIZONTAL CYLINDRICAL TANKS (ASSUMED FULL)
Upper Sample	1 part	1 part
Middle Sample	3 parts	8 parts
Lower Sample	1 part	1 part

(*b*) For horizontal cylindrical tanks that are only partially filled, the simple geometrically proportioned sampling levels, and composite sample mixtures stated above cannot give samples that are substantially proportionate to the volumes at the different depths, unless the tanks are filled to at least 80 per cent of the diameter. Each tank level may be worked out in accordance with the principle stated in Section 10.

(*c*) In referee tests, a mutually satisfactory selection of sampling levels and sample quantities at each level shall be mutually agreed upon if any departure from the methods specified are to be allowed.

(*d*) Table I gives a set of substantially correct sampling levels and sample quantities for partially filled horizontal cylindrical tanks, which may be used in the absence of other arrangements, employing values in the tabulation that lie nearest to the *actual filling depth.*

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[1] The all-levels sampling method is widely used for ship tanks, barges and large shore tanks. The method can not, however, give an average or a strictly representative sample, not only because the tank volume may not be proportional to the depth and because the operator can not move the sample container with a uniform speed, but also because the rate of filling the sample container is proportionate to the square root of the depth of immersion of the sample container opening below the surface.

Continuous Sample.

16. *Continuous Sample.*—A continuous sample is one obtained from a pipe or conduit conveying the material, in such a manner as to give at all times a representative average of all the sections and section velocities of the stream throughout the period of transit

Dipper Sample.

17. *Dipper Sample.*—A dipper sample is one taken by interposing a dipper or collecting vessel into the path of a free flowing stream, so as to collect a definite volume from the full cross-section of the stream at regular time intervals, or at time intervals so varied as to obtain samples in proportion to the amounts being delivered.

Mixed Sample.

18. *Mixed Sample.*—A mixed sample is one obtained by mixing or vigorously stirring the contents of the original container and pouring out or drawing off the quantity desired.

Thief Sample.

19. *Thief Sample.*—A thief sample is one taken by means of a sampling tube from a specified point in the containing vessel being sampled.

TABLE I.—SAMPLING LEVELS AND SAMPLE QUANTITIES FOR PARTIALLY FILLED HORIZONTAL CYLINDRICAL TANKS.

Liquid Depth, Percentage of Diameter	Sampling Level, Percentage of Diameter Above Bottom			Quantity of Sample to be Taken at Each Sampling Level		
	Upper	Middle	Lower	Upper	Middle	Lower
10	..	..	5	..	..	10 parts
20	..	..	10	..	..	10 "
30	..	20	10	..	6 parts	4 "
40	..	25	10	..	7 "	3 "
50	..	30	10	..	8 "	2 "
60	55	35	10	1 part	8 "	1 part
70	65	40	10	1 "	8 "	1 "
80	75	45	10	1 "	8 "	1 "
90	85	50	10	1 "	8 "	1 "
100	90	50	10	1 "	8 "	1 "

Drain Sample.

20. *Drain Sample.*[1]—A drain sample is one taken by opening the draw-off or the discharge valve and drawing off a suitable portion of the material.

Bottom Sample.

21. *Bottom Sample.*[1]—A bottom sample is one obtained by collecting a portion of the material lying on the bottom surface of the tank, container or line at its lowest point.

Borings Sample.

22. *Borings Sample.*—A borings sample is one obtained by collecting the chips made by boring holes with a ship auger from top to bottom of the material contained in a barrel, case, bag, or cake.

Grab Sample.

23. *Grab Sample.*—A grab sample is one obtained by collecting representative portions from loose solids in equal quantities from each part or package of a shipment, in sufficient amount to be representative of all the sizes and components.

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[1] Occasionally, as in tank cars, the drain sample will also give a bottom sample.

Drain samples and bottom samples are usually taken only in order to examine for moisture, sludge, scale, etc., and in some cases for the purpose of drawing off any free water or extraneous material.

GENERAL DIRECTIONS AND PRECAUTIONS

Official Samples. 24. Official samples shall be taken by, or under the immediate supervision of, a person of judgment, skill and previous experience in sampling.

Representativeness. 25. The portions taken for samples shall represent the general character and average condition of the lot sampled.

Check Samples. 26. If there is any substantial reason indicating that a sample or set of samples may not be fully representative, another sample or set of samples shall be taken.

Care of Crude Materials. 27. Great care and good judgment are necessary in taking and handling samples from crude or unrefined materials, not only because of possible segregation, sludging and volatilization, but because of the bearing upon value, refining problems, and methods of handling.

Care of Semi-Refined Materials. 28. A high degree of care shall be employed in handling samples from semi-refined materials upon which definite chemical and physical tests are usually made.

Special Precautions, Refined Materials. 29. The utmost precautions and the most meticulous care shall be exercised in handling samples from refined products, upon which special quality tests are usually made.

Contamination. 30. For all grades of materials, precautions shall be taken to assure that the sampling apparatus and the samples themselves are neither contaminated with *nor altered by any material* not representative of the lot being sampled.

Cleanliness of Operator. 31. The operator engaged in sampling shall have clean hands, free from any material (unless it be the material being sampled). Cleaned gloves may be worn, but only when absolutely necessary, as in extremely cold weather, or in handling materials at high temperatures, or materials involving some health or other hazard.

Cleanliness of Sampling Apparatus. 32. The sampling apparatus shall be thoroughly clean and dry, and free from any substance that will dissolve into and/or color water-white gasoline.

NOTE.—*Exception:* Crude and dark-colored semi-refined materials (such as dark-colored fuel oils) when fluid enough to drain completely from sampling apparatus (Saybolt universal viscosity less than 250 at 100° F.) may be sampled repeatedly with apparatus that has been hung up and thoroughly drained.

Marking and Recording Samples. 33. Samples shall be permanently marked (preferably with a pencil hard enough to dent the paper)[1] immediately after collection with the date, also the hour and minute for continuous and dipper samples, name of the sampler, name or number and owner of vessel, barge, car or container; material sampled, and a reference symbol or number. Thin aluminum strips stamped with the sample number and other information are acceptable. The reference symbol or number and other markings should be entered in a bound record book.

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[1] Soft pencil and ink markings are liable to obliteration from moisture, handling or smearing with oil.

Protection and Preservation of Samples.

34. Sample containers shall be closed immediately after collection. Sample containers shall be of such types as will protect the sample from contamination or deterioration. Specific precautions shall be taken as follows:

(*a*) Corks, for bottles, shall be clean, free from holes and loose bits of cork.

(*b*) Sealing wax, or paraffin, shall *not* be poured over corks after filling.

(*c*) Light-sensitive samples, when placed in bottles, shall be wrapped or otherwise covered at once, to protect them from light.

(*d*) Tin cans with screwed or overlapped and soldered caps are acceptable, but only if the inside has been scrupulously cleaned and known to be free from dirt, water, washing compounds, naphtha or other solvents, soldering flux or acids, corrosion, rust, and pin holes.

(*e*) Refined materials should be further protected by covers of paper or metal-foil over the stopper and top to keep moisture and dust away from the filling and emptying opening, and to protect it from contact with the hands. Covers also prevent sealing substances, such as wax or paraffin, from getting on the lip when the seal is made or later opened, and so getting into the sample when it is poured out.

(*f*) Samples shipped by mail, express or messenger shall be well packed to avoid spillage, leakage, breakage, and loss by evaporation or alteration while in transit.

Volatile Samples.

35. Volatile samples shall be protected from evaporation while being collected, particularly in the case of continuous and dipper samples, and at once placed in closed containers.

Time and Place of Sampling.

36. Samples shall, if possible, be taken at the time of loading of a shipment and at the point of origination of a shipment. When sampling at the point of origin has not been provided for, or is not feasible, then the sampling shall be carried out as soon as possible after receipt of the shipment.

Number of Packages Sampled.

37. Shipments consisting of a number of separate packages, such as cans, drums, barrels, or boxes, shall have a number opened and sampled equal to the cube root (or the next larger whole number) of the total number of packages in the lot.

Quantity and Sub-division of Samples.

38. (*a*) *Individual Liquid Samples.*—Individual liquid samples taken with a beaker, bottle or dipper shall be approximately 1 qt. or 1 liter.

(*b*) *Composite Liquid Samples.*—Composite liquid samples taken from vessels of all kinds and sizes shall be at least 5 qt. (or 5 liters) for vessels of uniform cross-section and 10 qt. (or 10 liters) for horizontal cylindrical tanks.

(*c*) *Gross Liquid Mixed Cargo Samples.*—Gross liquid mixed cargo samples taken from the various ship tanks shall have a total gross quantity corresponding to the number of tanks, that is, multiples of 5 to 10 qt., depending on the tank shapes.

(*d*) *Liquid Samples Taken by the Continuous Method or by the Dipper Method.*—Liquid samples taken by the Continuous Method, Section 50, or by the Dipper Method, Section 53, shall be approximately 0.1 per cent of the total quantity shipped, but not less than 5 U. S. gal. (or 20 liters) nor more than 40 U. S. gal. (or 160 liters).

(*e*) *Soft Solid Samples* (*Waxes, etc.*).—Soft solid samples taken by the Borings Method, Section 63, shall consist of three sets of borings $\frac{3}{4}$-in. in diameter and approximately the depth of the material.

(*f*) *Lumpy Solid Samples.*—Lumpy solid samples taken by the Grab Method, Section 66, shall be equivalent to approximately 0.1 per cent of the lot, but not less than about 50 lb. (25 kg.) nor more than 1000 lb. (500 kg.).

(*g*) *Sub-division of Gross Samples.*—Sub-division of gross samples shall be carried out in the laboratory and should be performed by someone from the laboratory staff, rather than by the person who originally took the samples. The sub-division shall be carried out in accordance with careful laboratory practice and the detailed directions given as a part of the procedure for each method.

CHOICE OF SAMPLING METHODS

Existing Sampling Methods.

39. (*a*) Where standard or tentative standard methods for sampling of the American Society for Testing Materials are already in existence, they shall be followed in detail in addition to the more general requirements appearing in these methods, and shall supersede them if there is a conflict.

NOTE.—Specifically this includes the following methods of sampling of the American Society for Testing Materials:

Standard Method of Sampling Coal (A.S.T.M. Designation: D 21);[1]

Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271);[2]

Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140).[3]

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 684.

[2] *Ibid.*, p. 689.

[3] *Ibid.*, p. 669

Sampling Requirements in Existing Test Methods. (*b*) Where special conditions exist in regard to the quality of the material and/or the method of test, and particularly when existing standard or tentative standard methods of tests of the American Society for Testing Materials call for special precautions or methods for sampling, they shall be followed in detail in addition to the requirements appearing in these methods and shall supersede them if there is a conflict.

NOTE.—Specifically this includes the following methods of test of the American Society for Testing Materials:

Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117);[1]
Standard Method of Analysis of Grease (A.S..T.M. Designation: D 128);[2]
Tentative Method of Test for Penetration of Greases and Petrolatum (A.S.T.M. Designation: D 217 - 27 T).[3]

Alternative Sampling Methods. 40. Alternative methods for sampling shall be employed only after a mutually satisfactory agreement shall have been reached by persons authorized to act on this question. The agreement shall be put in writing and signed by competent officials.

Liquid Materials. 41. Liquid materials may be sampled by the Bottle or Beaker, Thief, Continuous, or Dipper Method, in accordance with the type of container, as described below:

Cars and Tanks. (*a*) Tank cars, tank trucks, shore tanks, ship tanks and barge tanks shall be sampled by the Bottle or Beaker Method as described in Sections 45, 46, and 47, for upper, middle and lower samples (Sections 12, 13 and 14), from which a composite sample for all referee tests shall be made up in accordance with Section 15. Tank cars of insulating oil shall be sampled with a tank car thief as described in Sections 54 to 58, inclusive.

The all-levels sample, Section 11, is convenient in practice but shall be employed for routine work only.

Pipe Lines. (*b*) Pipe lines shall be sampled by the Continuous Method as described in Sections 48, 49 and 50.

Small Pipe and Open Discharge Lines. (*c*) Small pipe lines (approximately 2 in. in diameter or less) ending in an open discharge, or where an open discharge is permissible, may be sampled by the Dipper Method as described in Sections 51, 52 and 53. In the absence of an open discharge, a larger diameter pipe nipple may be placed in a vertical section of the pipe line and the Continuous Method used as described in Sections 48, 49 and 50.

Cans, Drums or Barrels. (*d*) Cans, drums or barrels shall be sampled by the Thief Method as described in Sections 54 to 59, inclusive, except that small cans, less than 5 gal. capacity, *may* be taken complete. Containers shall have their

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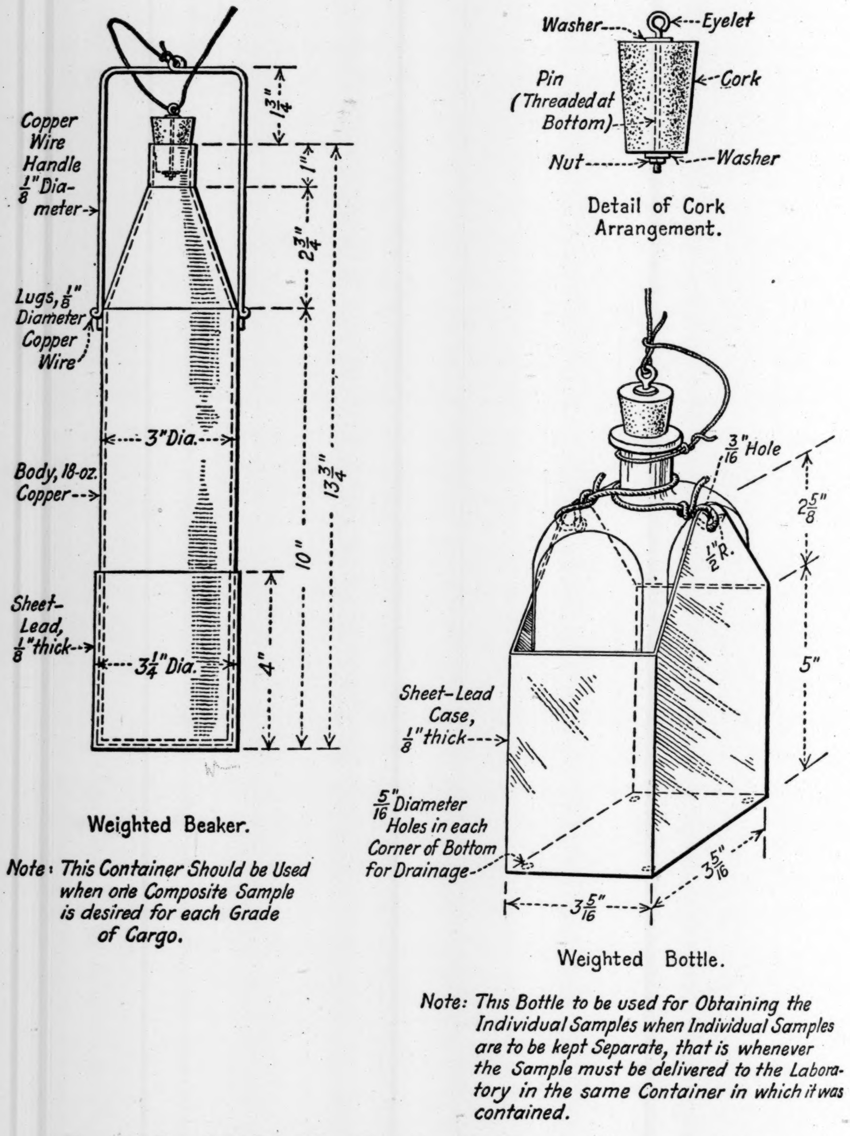
[1] 1930 Book of A.S.T.M. Standards, Part II, p. 1004.

[2] *Ibid.* p 452

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 930 (1927); also 1930 Book of A.S.T.M. Tentative Standards, p. 381.


Copper Wire Handle $\frac{1}{8}$" Diameter
Lugs, $\frac{1}{8}$" Diameter Copper Wire
Body, 18-oz. Copper
Sheet-Lead, $\frac{1}{8}$" thick
$1\frac{3}{4}$"
1"
$2\frac{3}{4}$"
$13\frac{3}{4}$"
10"
4"
3" Dia.
$3\frac{1}{4}$" Dia.
Washer
Eyelet
Pin (Threaded at Bottom)
Cork
Nut
Washer
Detail of Cork Arrangement.
$\frac{3}{16}$" Hole
$2\frac{5}{8}$"
$\frac{1}{2}$" R.
5"
Sheet-Lead Case, $\frac{1}{8}$" thick
$\frac{5}{16}$" Diameter Holes in each Corner of Bottom for Drainage
$3\frac{5}{16}$"
$3\frac{5}{16}$"

Weighted Beaker.

Note: This Container Should be Used when one Composite Sample is desired for each Grade of Cargo.

Weighted Bottle.

Note: This Bottle to be used for Obtaining the Individual Samples when Individual Samples are to be kept Separate, that is whenever the Sample must be delivered to the Laboratory in the same Container in which it was contained.

FIG. 1.—Standard Sampling Containers for Bottle or Beaker Sampling.

contents thoroughly mixed by being rolled or shaken to allow the taking of a mixed sample, Section 18, with the thief.

Semi-Liquid Materials. 42. Semi-liquid materials shall be warmed till they are sufficiently fluid to be sampled as liquid materials as described in Section 41.

Soft Solid Materials. 43. Soft solid materials shall be sampled by the Borings Method as described in Sections 61, 62 and 63.

Lumpy Solid Materials. 44. Loose lumpy solid materials shall be sampled by the Grab Method as described in Sections 64, 65 and 66.

BOTTLE OR BEAKER SAMPLING

Scope. 45. The bottle or beaker method of sampling is applicable to the following types of containers:

(*a*) Tank cars and/or tank trucks;

(*b*) Shore tanks;

(*c*) Ship tanks and barge tanks.

APPARATUS[1]

Sampling Bottle and Beaker. 46. The sampling bottle and sampling beaker shall be made substantially in accordance with the form and dimensions shown in Fig. 1, with the size of opening as follows:

	Size of Opening	
Class of Material	Weighted Sampling Bottle	Weighted Sampling Beaker
Heavy crudes and fuel oils	...	$1\frac{1}{2}$ in.
Light crudes and full cargoes of Diesel fuels, distillates or non-transparent gas oils	...	$\frac{3}{4}$ in.
Heavy lubricating oils	$1\frac{1}{2}$ in.	...
Light lubricating oils, kerosine, gasoline, transparent gas oils, also part cargoes of Diesel fuel, distillates or non-transparent gas oils	$\frac{3}{4}$ in.	...

PROCEDURE[2]

Procedure. 47. The following instructions shall apply to a substantially full tank.

(*a*) An upper sample shall be taken by lowering the weighted stoppered bottle or beaker till its mouth is 10 per cent of the depth of a tank of uniform cross-section or diameter of a horizontal cylindrical tank below the surface, uncorking it by a quick jerk, allowing it to fill completely, as evidenced by cessation of air bubbles, and then immediately withdrawing it.

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[1] This description is adapted from "Instructions for Measuring, Sampling and Testing Bulk Oil Cargoes," Standard Oil Co. of New Jersey, pp. 20–22 (1926).

[2] This procedure is adapted from "Instructions for Measuring, Sampling and Testing Bulk Oil Cargoes," Standard Oil Co. of New Jersey, p. 21 (1926).

(*b*) Three middle samples shall be taken in a similar manner from a tank of uniform cross-section and eight middle samples from a horizontal cylindrical tank with the bottle or beaker mouth lowered to the middle of the tank.

(*c*) A lower sample shall be taken in a similar manner with the bottle or beaker mouth lowered to a point 10 per cent of the depth of a tank of uniform cross-section or diameter of a horizontal cylindrical tank above the bottom of the tank.

(*d*) The upper, middle, and lower samples from each tank car, tank truck, shore tank, individual ship tank or barge tank shall be combined into a composite sample.

(*e*) The composite samples taken with the beaker from the various ship tanks shall be combined into a mixed cargo sample for:

> *All Unfinished Products,* including crude oils and bunker fuel;
> *Full Cargoes* of Diesel fuel, distillates, and non-transparent gas oils.

(*f*) The beaker samples shall be poured as taken into a clean 5 or 10-gal. can, or cans, and the cans closed and covered, labeled and delivered to the laboratory, shaken or mixed with the churn dasher type of stirrer, Section 49 (*b*), and portions withdrawn by means of a thief for test.

(*g*) The composite samples taken with the bottle from the various ship tanks shall be kept separate and delivered separately to the laboratory for:

> *All Finished Products,* including gasoline, kerosine, lubricating oils, and transparent gas oils;
> *Part Cargoes* of Diesel fuel, distillates, and non-transparent gas oils.

(*h*) The bottle samples shall all be delivered to the laboratory in the bottle in which they were taken.

(*i*) When loading or discharging any finished product, samples shall also be taken from the shore tanks and at frequent intervals from the shore pipe line on the dock. These samples shall also be tested whenever it seems advisable.

(*j*) A portion of all samples from all shipments shall be fully labeled and kept in storage until the final disposition of the material.

(*k*) Ship and barge tanks should be sampled not only immediately after loading, but also before discharging.

CONTINUOUS SAMPLING

Scope.

48. The continuous method of sampling is applicable to the following conditions and types of containers:

(*a*) Pipe lines;
(*b*) Filling lines;
(*c*) Transfer lines.

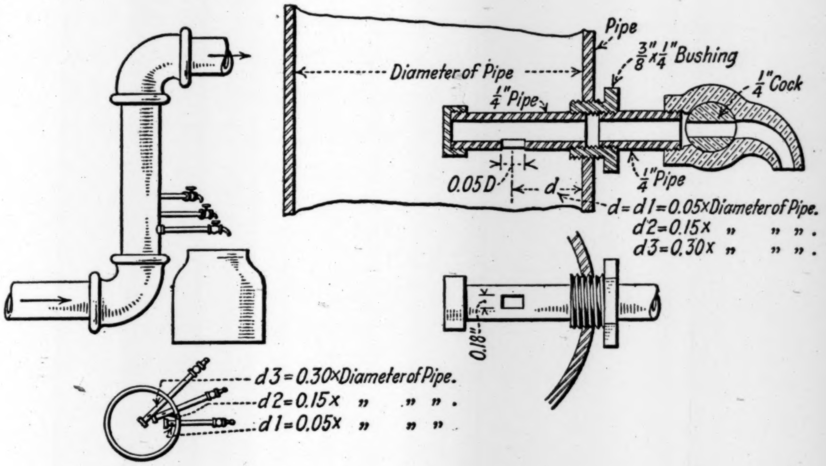
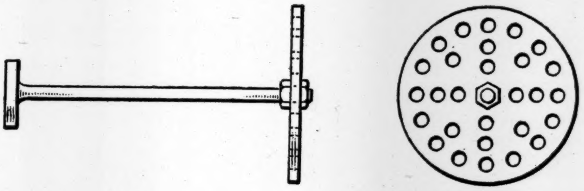

Pipe
3/8"x1/4" Bushing
1/4" Cock
Diameter of Pipe
1/4" Pipe
0.05D
d
1/4" Pipe
d = d1 = 0.05×Diameter of Pipe.
d2 = 0.15× " " ".
d3 = 0.30× " " ".
0.18"
d3 = 0.30×Diameter of Pipe.
d2 = 0.15× " " ".
d1 = 0.05× " " ".

FIG. 2.—Continuous Sampling Connection.



Perforations 1in. in Diameter.

FIG. 3.—Churn Dasher Type of Stirrer.

APPARATUS

Continuous Sampling Connection.

49. (*a*) The continuous sampling connection shall be constructed and installed in accordance with the form and dimensions shown in Fig. 2.

Churn Dasher Stirrer.

(*b*) The churn dasher type of stirrer shall conform to the form and dimensions shown in Fig. 3.

PROCEDURE[1]

Procedure. 50. The three plug cocks shall be opened, as nearly as possible, to the same angle of opening, so that a steady stream is drawn off from each cock and at such a rate as will allow about 0.1 per cent of the stream to be diverted during the passage of the lot being sampled, but not more than 40 U. S. gal. The following precautions should be observed.

(*a*) For semi-liquid materials, the receiver, or receivers, shall be kept warm by means of steam coils adjusted to keep the material just above the liquefying temperature.

(*b*) The receiver, or receivers, should be kept covered and closed except for their vents and filling stream openings, or pipes.

(*c*) Screens of larger area than the openings may be placed around the $\frac{1}{4}$-in. pipes or $\frac{1}{4}$-in. screen fittings inserted in the drip lines.

(*d*) A pipe cap with a suitable orifice hole may be substituted for the cocks, where the orifice size has been predetermined so as to give the right amount of sample.

(*e*) The gross continuous sample as collected shall be stirred with the churn dasher type of stirrer, or mixed by rolling or shaking, and then sampled by means of a thief to get a 1-qt. sample, or more where larger quantities may be desired and are called for.

DIPPER SAMPLING

Scope. 51. The dipper method of sampling is applicable where a free or open discharge of a stream exists or can be obtained readily, as follows:

(*a*) Small filling and transfer pipe lines (2 in. in diameter or less);

(*b*) Package, can or barrel filling apparatus.

APPARATUS

Dipper. 52. The dipper shall have a flared bowl holding approximately 1 qt. (or 1 liter) and a handle of any convenient length. Tinned steel is acceptable.

PROCEDURE[1]

Procedure. 53. (*a*) The dipper shall be inserted in the free flowing part of the stream, collecting a sample from the full cross-section of the stream at regular intervals, and the sample collected poured into a clean can of a convenient size, such as 5 or 10-gal. capacity.

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[1] This procedure has been adapted from the Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140) of the American Society for Testing Materials, 1930 Book of A.S.T.M. Standards, Part II, p. 669.

(*b*) If the pumping or delivery rate varies, the samples shall be taken at time intervals so chosen as to give a sample for equal pumped quantities.

(*c*) The container into which the individual dipper samples of approximately 1 qt. each are poured shall be kept closed and covered except when the close-fitting lid and cover are lifted to pour in the dipper sample.

(*d*) The gross amount of material collected should be about 0.1 per cent of the quantity transferred, and the time intervals should be so chosen as to correspond, but not less than 5 gal. nor more than 40 gal. should be collected.

(*e*) The 5 or 10-gal. can shall be closed and covered, labeled and delivered to the laboratory, where it shall be shaken or mixed with the churn dasher type of stirrer and portions withdrawn by means of a thief for test.

THIEF SAMPLING[1]

Scope.

54. The thief method of sampling is applicable to the following types of containers:

(*a*) Cans;
(*b*) Drums or barrels;
(*c*) Tanks cars.

APPARATUS

Sampling Thiefs.

55. (*a*) *General.*—Thiefs shall be used for withdrawing samples of oil from drums, tank cars, or other containers of 5-gal. capacity or larger in which shipment is made. Glass or metal thiefs may be used.

(*b*) *For Drums.*—For sampling drums the thiefs shall be so designed that they will reach within approximately ⅛ in. (about 3 mm.) of the bottom and should have a capacity of approximately 1 pt. or 1 qt. (0.5 or 1 liter).

NOTE.—A convenient and simple thief for sampling 50-gal. drum containers is shown in Fig. 4, which illustrates a sheet metal thief 36 in. in length, 1¼ in. in diameter, with cone-shaped caps over the ends and having openings at the ends ⅜ in. in diameter. Three legs, equally spaced around the thief at the lower end, long enough to hold the opening ⅛ in. from the bottom of the container, aid in securing a good representative sample. Two rings soldered to opposite sides of the tube at the upper end will be found convenient for holding the thief by slipping two fingers through them, leaving the thumb free to close the opening.

(*c*) *For Cans.*—For sampling cans of 5-gal. capacity or larger a thief, similar to that used for sampling drums but of proportionately smaller dimensions, shall be used. Cans of less than 5-gal. capacity shall be taken as a whole (see Paragraph 59 (*e*)).

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[1] This procedure has been adapted from the Tentative Revision of the Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117 - 27) of the American Society for Testing Materials, see, p. 1284.

(*d*) *For Tank Cars.*—For sampling tank cars the thief shall be so designed that the sample may be obtained from within at least 0.5 in. of the bottom.

NOTE.—A thief suitable for sampling tank cars may be made from metal tubing and castings, machine-finished all over. A valve rod, whose projecting stem strikes the bottom of the car, opens the valve automatically and simultaneously releases the air through the top. Such a thief is illustrated in Fig. 5.

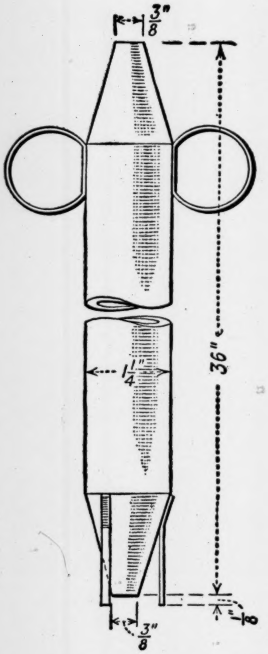


FIG. 4.—Thief for Sampling Drums.

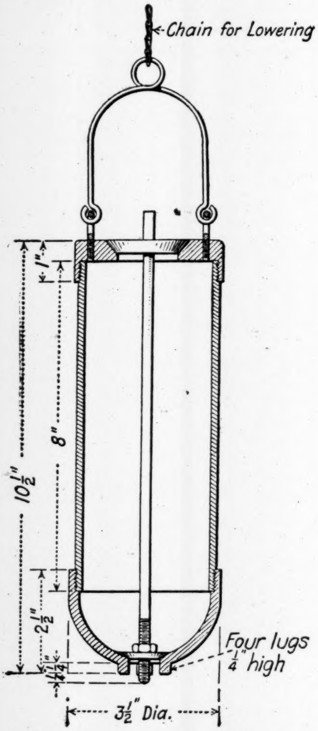


FIG. 5.—Thief for Sampling Tank Cars.

Sample Containers. 56. Tin cans or cork or glass-stoppered clear-glass bottles in cartons may be used as containers for the samples. The containers shall be clean and dry.

NOTE.—The clear-glass bottle offers the advantage that it may be examined to see that it is clean. It also allows visual inspection of the oil before testing, permitting the detection of free water or solid impurities. However, if samples are placed in glass bottles, they shall be kept in the dark until portions are removed for testing for color and sludge forming characteristics, as light produces changes in these properties. For this reason cardboard cartons with covers shall be provided for each bottle into which the bottle with its sample of oil shall be placed immediately after sampling. Rubber stoppers shall never be used. If cork is used it shall be of good quality with a new cork for each sample. Contact of the oil with the cork may be prevented by wrapping some tin or aluminum foil around the cork before forcing it into the mouth of the bottle. If glass-stoppered bottles are used precautions shall be taken to insure that perfectly fitting stoppers are secured. A tin can fitted with a screw cap protected with a cork disk faced with tin or aluminum will endure harder usage. If tin cans are to be employed, only those having seams soldered on the exterior surfaces shall be used.

Cleaning of Sampling Apparatus.

57. (*a*) *General.*—All thiefs and sample containers shall be cleaned thoroughly before using, special care being taken that no lint or other fibrous material remains in or on them. Care shall be taken to insure the complete removal of all traces of soldering flux from new thiefs and new cans.

NOTE 1.—Thiefs and containers that are not chemically clean and dry are likely to contaminate the samples and cause misleading results on some of the tests.

NOTE 2.—To insure the greatest ease in removing traces of soldering flux, a flux of rosin in a suitable solvent is recommended for soldering all seams. Such a flux is easily removed with gasoline, whereas, many other fluxes are very hard to remove. Minute traces of flux may contaminate the sample so that the results obtained on dielectric strength tests and various sludge tests may be erroneous.

(*b*) *Thiefs.*—Thiefs, before using, shall be cleaned by rinsing with oil-free gasoline and dried in the hot cabinet described in Section 58 (*a*). The best procedure is to rinse them after the sampling has been finished and then place them in the hot cabinet, as in this way they will be ready for use without further cleaning when the next shipment is to be sampled.

(*c*) *Sample Containers.*—Sample containers, before using, shall be rinsed with oil-free gasoline and dried. They shall then be washed with strong soapsuds, rinsed thoroughly with distilled water and then dried by passing a current of warm air through the containers, after which they shall be immediately placed in the hot cabinet described in Section 58 (*a*). A similar washing will be sufficient for re-use of the containers that have held new oil, but those which have contained used oil shall be washed with both gasoline and benzol before being washed with soapsuds.

Storage of Sampling Apparatus.

58. (*a*) *General.*—When not in use all thiefs and sample containers shall be kept in a hot, dry, dust-free cabinet or compartment at a temperature not less than 38° C. (100° F.).

(*b*) *Thiefs.*—Thiefs shall be kept at all times in a vertical position in the hot cabinet in a rack having a suitable drainage receptacle at the base.

(c) *Sample Containers.*—Containers for samples, after washing and drying as described in Section 57(c), shall be kept unstoppered while in the hot cabinet but shall be closed immediately on removal. When containers must be prepared in advance and can not be kept in the hot cabinet until approximately the time for the sample to be placed therein (as for example, when bottle containers are prepared to be sent to a distant sampling point) the same procedure of washing and drying shall be followed as described in Section 57 (c). In such instances, after the bottles are corked or stoppered and removed from the hot cabinet, the corks or stoppers shall be capped with paper which is tied securely on the neck, and then the capped corks or stoppers shall be sealed by dipping into melted paraffin wax so as to cover all of the paper cap and part of the neck. If this procedure is followed, care shall be taken in removing the paraffined caps preparatory to filling the bottles with samples, that no paraffin contaminates the sample.

PROCEDURE

Procedure for Sampling New Oils.

59. *Procedure for Sampling New Oils.*—(a) A sufficient number of samples shall be taken to cover the requirements of the tests. It is recommended that 1 qt. of oil be taken as a sample if complete physical and chemical tests are to be made and at least 1 pt. if only the dielectric strength tests are to be made.

NOTE.—Samples of insulating oils shall be taken and handled in such a manner that the tests made upon them indicate the characteristics of the shipment. Some tests are greatly affected by the most minute traces of impurities. This is particularly the case with the sludge test and the dielectric strength test, the latter being affected by almost infinitesimal traces of moisture. If these tests are to be made, it is important that the samples be handled with the utmost care to prevent such contamination. All tests are usually made on samples taken from drums. Sometimes dielectric strength tests are not made on samples taken from tank cars. Samples from tank cars are usually tested only for the physical and chemical properties that are not affected by *slight* amounts of moisture; care, however, shall be taken to prevent extraneous contamination of the samples, as contamination might affect the sludge test. It is imperative, therefore, that the procedure and precautions for obtaining and transporting samples of the oil to be tested, as specified in Sections 55 to 60, inclusive, shall be observed.

(b) Drums, tank cars, or other containers of insulating oil shall not be sampled until the oil is at least as warm as the surrounding air, because cold oil may condense enough moisture from a humid atmosphere to affect seriously its insulating properties. Samples shall, of course, never be taken in the rain and precautions shall be taken during sampling to prevent contamination such as that which may occur from wind-blown dust or other sources.

(*c*) Samples of insulating oil from drums and cans shall be taken only after the oil has remained undisturbed for at least eight hours. The containers for oils other than electrical insulating oil shall have their contents thoroughly mixed by being rolled or shaken, so that a mixed sample may be taken with the thief.

(*d*) Drums and barrels of oil to be sampled shall be lined up, preferably on their sides with their bungs up. The bungs shall be unsealed, removed, and laid with the oily sides up beside the bung holes. The top hole of the thief shall be closed with the thumb and the thief thrust about 1 ft. (30 cm.) into the oil. The thumb shall then be removed, allowing the oil to flow into the thief. The upper end of the thief shall again be closed with the thumb and the thief withdrawn. The oil remaining in the thief shall be used for rinsing out the thief by holding the thief nearly horizontal and turning so that the oil comes in contact with that part of the inside surface of the thief which is immersed when taking the final sample. During this rinsing of the thief care shall be taken to avoid handling any portion of the thief that is subsequently immersed in the oil to be sampled, as moisture from the fingers or hands may be sufficient to cause enough contamination of the oil to cause a low value in dielectric strength test. The oil used for rinsing shall be thrown away and the thief allowed to drain. The thief shall again be inserted into the oil but this time the thumb is not removed until the thief reaches the bottom of the container. When the thief is filled, the thumb shall be replaced, the thief quickly withdrawn and the contents allowed to flow into the sample container. The bottom hole shall not be closed with the fingers of the other hand. The free hand shall be used to guide the stream of oil by touching the thief only as necessary. The oil shall not be allowed to flow over the hand or fingers before it flows into the sample container nor shall any excess be allowed to flow over the drum or barrel and back again through the open bung hole. When the sample container is filled it shall be closed quickly and the bung replaced in the drum and tightened. The sample container shall be labeled at once and taken to the testing laboratory as quickly as feasible.

(*e*) Smaller containers such as cans of 5-gal. capacity or larger shall be sampled with a thief, similar to the drum thief but of proportionately smaller dimensions, using a method similar in general to the one described for drums and barrels in Paragraph (*d*). To sample a shipment of cans of less capacity than 5-gal. one or more cans shall be selected at random from the shipment, using the entire can or cans as the sample.

(*f*) Tank cars of oil shall be sampled by introducing the tank-car thief through the manhole on top of the car, the cover of which shall be removed carefully so as not to introduce any dirt into the oil. The thief shall be lowered until it strikes the bottom of the tank car, when it automatically opens and fills. Under no conditions shall samples be taken from the bottom draw-off.

(*g*) When separate samples are being taken from a consignment or part of a consignment care shall be exercised to prevent contaminating the samples. A separate thief shall be used for each sample or the thief previously used shall be well drained and then thoroughly washed with oil from the next container to be sampled, throwing away the oil thus used for washing, before taking the portion reserved for the sample (see Paragraph (*d*)). Enough thiefs shall be provided to insure that each thief shall be thoroughly drained after rinsing with the oil to be sampled before it is used to withdraw the sample. For obtaining only a few samples two thiefs are enough, but for obtaining a large number of samples (for example, sampling a carload of drummed oil) six or more are desirable.

(*h*) When one average sample of a consignment or batch is being taken the same thief may be used throughout the sampling operation, omitting the precaution of rinsing the thief with oil before taking any of the portions that make up the total average sample.

Procedure for Sampling Oils in Service.

60. *Procedure for Sampling Oils in Service.*—When taking samples of oil from transformers, oil circuit breakers, and similar electrical apparatus where a thief can not be used, the precautions outlined in the preceding sections shall be observed so far as practicable. In addition, care shall be taken to procure a sample that represents fairly the oil at the bottom of the tank. Transformer and oil circuit-breaker tanks and similar electrical apparatus are usually provided with drain pipes or sampling cocks from which the sample may be allowed to flow into the sample container. Before the sample is taken, enough oil shall first be allowed to flow to waste through these drain pipes or sampling cocks to insure that the sample will not be that portion which was stored in the drain pipe. For this reason, the valve and the drain pipe should be small enough to be emptied with convenience and yet large enough to give an even flow of oil and avoid clogging by sediment. A U. S. Standard $\frac{1}{4}$-in. nominal size pipe (equivalent to an inside diameter of approximately 9 mm.) with suitable valve is recommended. This, of course, may be separate from the drainage pipe and valve or may be connected to the drainage valve by means of a suitable reducer.

BORINGS SAMPLING

Scope. 61. The borings method of sampling is applicable to wax and soft solids in cases, cakes, bags or barrels, when they cannot properly or conveniently be melted and sampled as liquids.

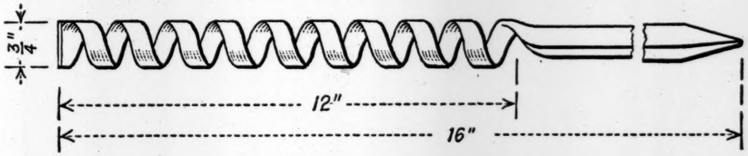
APPARATUS

Ship Auger. 62. The ship auger shall be $\frac{3}{4}$ in. in diameter and shall conform to the form and dimensions shown in Fig. 6, and be of such a length as to pass entirely through the material to be sampled.

PROCEDURE

Procedure. 63. (*a*) *Opening.*—Cases and barrels shall have the covers or heads removed. Bags shall have the mouths opened. Cakes shall have the wrappings, if any, opened.

(*b*) *Foreign Matter.*—If foreign substances, such as dirt, sticks, string, etc., appear upon the surface, they shall be removed. Foreign matter found in the interior shall be included, as it may come, with the borings.



Note: Greater Overall Lengths may be obtained when necessary to pass entirely through the Material to be sampled.

FIG. 6.—Improved Ship Auger.

(*c*) *Boring Hole Location.*—Three test holes shall be bored through the body of the material as follows:

One at the center;

One at one-quarter of the diameter (or width of the package) from the right side;

One at one-quarter of the diameter (or width of the package) from the left side.

(*d*) If any visible differences appear in the three sets of borings, they shall be preserved, examined and tested separately.

(*e*) If no visible differences appear in the borings they may be combined, preserved, examined and tested as a single sample, but this shall be done only after the three sets of borings have been delivered to the laboratory and by the laboratory tester.

(*f*) *Sub-division.*—If sub-division of the borings is desired, they may be chilled, pulverized if necessary for handling, mixed, and quartered till reduced to the amount desired, after their receipt in the laboratory. This sub-division shall not be done in the field by the sampler.

GRAB SAMPLING

Scope. 64. The grab method of sampling is applicable to all lumpy materials loose in bins, bunkers, or carried in sacks, barrels or boxes.

APPARATUS

Apparatus. 65. A shovel if employed for sampling[1] may be of any convenient size, but should have a width at least twice as great as the maximum dimension of the largest pieces sampled.

PROCEDURE[2]

Procedure. 66. (*a*) Solids are almost always heterogeneous in constitution. It is impossible to give absolutely definite and arbitrary methods for obtaining samples. Each problem must be worked out for itself, bearing in mind the particular conditions.

(*b*) It is usually preferable to take samples during the unloading of cars or during transit of the material in conveyors. In such instances, a number of small samples should be taken at frequent and regular intervals from the material in transit and these samples combined to form a representative combined sample.

(*c*) Occasionally, solids are tested as received in bags or barrels. In such instances, it is desirable to take a small sample from a number of packages selected at random and equivalent in number to the cube root (or the next larger whole number), of the total number of packages in the lot.

(*d*) Generally, samples taken from the bulk, in piles or cars, are unreliable and not representative. Where it is necessary to take such samples before the unloading of the car, small samples should preferably be taken from at least twelve spots throughout the bulk and these small samples collected to form the representative combined sample. In taking such small samples, it is desirable to take eight samples from the corners of the car, four near the bottom and four near the top of the material. To those should be added four samples from the center of the car, two at the top, and two near the bottom of the material.

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[1] See the Standard Methods of Sampling Bituminous Materials (A.S.T.M. Designation: D 140) of the American Society for Testing Materials, 1930 Book of A.S.T.M. Standards, Part II, p. 669.

[2] The Standard Method of Sampling Coal (A.S.T.M. Designation: D 21), 1930 Book of A.S.T.M. Standards, Part II, p. 684, gives very full instructions and may be very helpful in directing the sampling of any loose bulk material.

(*e*) The combined sample taken by any of the above methods should be in amount at least 0.1 per cent of the total bulk of material sampled. These combined samples should be carefully mixed and reduced in size to a convenient laboratory sample, by the standard method of quartering. In carrying out this quartering, a hard clean surface should be selected, free from cracks and protected from rain, snow, wind and beating sun. Cinders, sand, chips from the floor or any other material shall be avoided. The sample shall be protected from loss or gain in moisture or dust. The combined sample should be carefully mixed, spread out on the surface into a circular layer and divided into four equal quadrants. Two opposite quadrants shall be combined to form the representative reduced sample. If this sample is still too large for laboratory purposes, the quartering operation shall be repeated. In this manner, the sample shall finally be reduced to a size suitable for handling in the laboratory.

(*f*) The use of a riffle sampler as described in the Standard Methods of Laboratory Sampling and Analysis of Coal and Coke (A.S.T.M. Designation: D 271) of the American Society for Testing Materials[1] is also recommended, with proper precautions against loss of dust for sub-division in the laboratory.

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[1] 1930 Book of A.S.T.M. Standards, Part II. p. 689.

TENTATIVE METHOD OF TEST
FOR
DILUTION OF CRANKCASE OILS[1]

A.S.T.M. Designation: D 322 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. This method is intended for the determination of the amount of dilution in crankcase oils of engines when gasoline has been used as the fuel.

APPARATUS

Apparatus. 2. (*a*) *General.*—The apparatus shall consist of a glass flask, heated by a gas-burner flame, and provided with a reflux water condenser discharging into a trap for collecting the distillate. The trap serves to collect and measure the diluent, returning condensed water to the still.

(*b*) *Trap.*—The trap shall be made of well-annealed glass constructed in accordance with Fig. 1. It shall be graduated from 0 to 12.5 ml. in 0.1-ml. divisions. The error of any indicated capacity shall not be greater than 0.05 ml.

(*c*) *Flask.*—The glass flask shall be of the short-neck, round-bottom type, with a nominal capacity of 1 liter.

(*d*) *Condenser.*—The condenser shall be of the water-cooled, reflux, glass-tube type, having a condenser jacket not less than 400 mm. ($15\frac{3}{4}$ in.) in length with an inner tube 9.5 to 12.7 mm. ($\frac{3}{8}$ to $\frac{1}{2}$ in.) in outside diameter. The end of the condenser to be inserted in the trap shall be ground off at an angle of 60 deg.

(*e*) *Burner.*—The gas burner shall preferably be of the Meeker type, 1 in. in diameter, and the orifice used should be such that a narrow flame coming to a point about 4 in. above the top of the burner can be obtained.

PROCEDURE

Procedure. 3. The sample shall be mixed thoroughly, and 25 ml. shall be measured into a 25-ml. graduate and transferred to the flask. By washing out the graduate with hot water only a negligible amount of oil will be left in the graduate. Approximately 500 ml. of water shall then be added to the flask and the apparatus shall be assembled, after filling the trap with water. The tip of the condenser shall be placed directly over the indentation in the trap.

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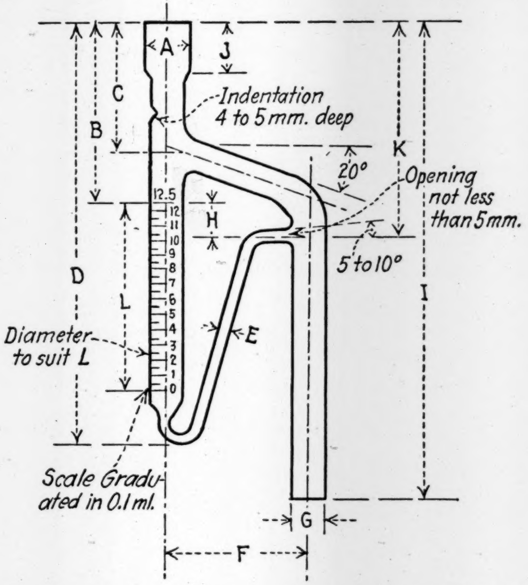
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

Heat shall be applied with the full flame as indicated above. The rate (Note 1) shall be such that refluxing starts within from 7 to 10 minutes after the heat is applied, the water being at room temperature initially. The success of the method depends upon heating at such a rate that boiling is continuous and vigorous enough to prevent the oil from forming, even momentarily, a continuous film on top of the water. (Note 2.)



A......	18 to 20 mm., inside diameter	*G*.......	11 to 15 mm., inside diameter
B......	85 " 90 mm.	*H*.......	15 " 20 mm.
C......	70 " 75 mm.	*I*......	230 " 250 "
D......	200 " 225 mm.	*J*......	25 " 30 "
E......	4 " 5 mm., inside diameter	*K*......	100 " 110 "
F.	65 " 75 mm.	*L*.......	90 " 100 "

FIG. 1.—A.S.T.M. Dilution Trap.

NOTE 1.—As a check on the rate of distillation, a determination may be made on a fresh oil containing 15 per cent of added diluent. The oil used should have a flash point of 400° F. or over and the diluent used should have an initial boiling point of 300 to 320° F. and an end point of 400 to 420° F. At least 13.5 per cent of the diluent should be obtained by this method on boiling for 60 minutes.

NOTE 2.—Bumping with a tendency to froth over is often experienced with dirty oils and may be prevented in several ways, namely, by the addition of bits of broken glass, by the addition of steel wool, or by the addition of about 5 ml. of concentrated HCl.

Readings of the amount of diluent shall be made at the following times, taken from the time that refluxing starts: 5, 15 and 30 minutes, and each 15 minutes following, until the test is complete. Completion of the test shall be determined on the basis of either or both of the following criteria:

No. 1.—Test is complete when the volume of diluent increases by not more than 0.1 ml. in any 15-minute period during the course of the test.

No. 2.—Test is complete when the volume of diluent obtained in a given time indicates completion, as follows:

TIME FROM START OF REFLUXING	TEST IS COMPLETE IF APPARENT VOLUME OF DILUENT COLLECTED IS EQUAL TO OR LESS THAN
5 minutes	0.1 ml.[a]
30 "	2.0 ml.
60 "	4.0 ml.
90 "	7.0 ml.

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[a] Report as "no dilution."

Generally criterion No. 1 defines the completion of the test, but when the test continues to a point at which any of the conditions described under criterion No. 2 are encountered, the latter shall define the completion of the test.

When the test is complete by either of the criteria above the heat shall be turned off. After standing at least 15 minutes, to allow the distillate to settle clear and to cool to approximately room temperature, the volume of diluent shall be read. The percentage dilution is obtained by multiplying this final volume by 4.

Accuracy. 4. Determinations by independent operators should agree within 20 per cent for dilutions under 5 per cent and within 10 per cent for dilutions over 5 per cent. Duplicate determinations by the same operator should, in general, show a closer agreement than the above.

TENTATIVE METHOD OF TEST
FOR
DISTILLATION OF CRUDE PETROLEUM[1]

A.S.T.M. Designation: D 285 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928; REVISED, 1929, 1930.

Scope

1. This method is intended for determining the percentages and distillation range of the naphtha in any crude oil of the class commercially known as refinable crudes. This method does not attempt to specify what quality of product shall be defined as naphtha nor can it be expected to duplicate the results of commercial refining operations. It defines apparatus and procedure, leaving selection of numerical limits and interpretation of results to be agreed upon by the interested parties.

APPARATUS

Flask.

2. *Flask.*—The distillation flask shall be a 300-ml. Hempel distilling flask, Fig. 1, the dimensions and allowable tolerances being as follows:

			TOLERANCES	
	CENTIMETERS	INCHES	CENTIMETERS	INCHES
Diameter of bulb, outside...	10.2	4.0	±0.2	±0.08
Diameter of neck, outside...	2.9	1.125	±0.1	±0.04
Length of neck............	25.4	10.0	±0.4	±0.16
Distance, top of neck to center of vapor tube......	6.4	2.5	±0.3	±0.12
Length of vapor tube......	17.2	6.75	±0.5	±0.20
Diameter of vapor tube, outside..................	0.8	0.3125	±0.1	±0.04

The vapor tube shall be set at an angle of 75 deg. ± 5 deg. with the neck of the flask.

Fractionating Column.

3. *Fractionating Column.*—The fractionating column (see *a*, Fig. 2) shall be made of a length of No. 18 iron jack chain, enough to pack under its own weight into a column 2.54 cm. (1 in.) in diameter and 17.51 cm. (6½ in.) in length. It may conveniently be "strung" on a

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

loop of wire so that it hangs in loops about 2 ft. in length, which makes the chain more convenient to handle than when it is not looped together. The device used for supporting the column (see *b*, Fig. 2) shall be made of a suitable length of wire, preferably, though not

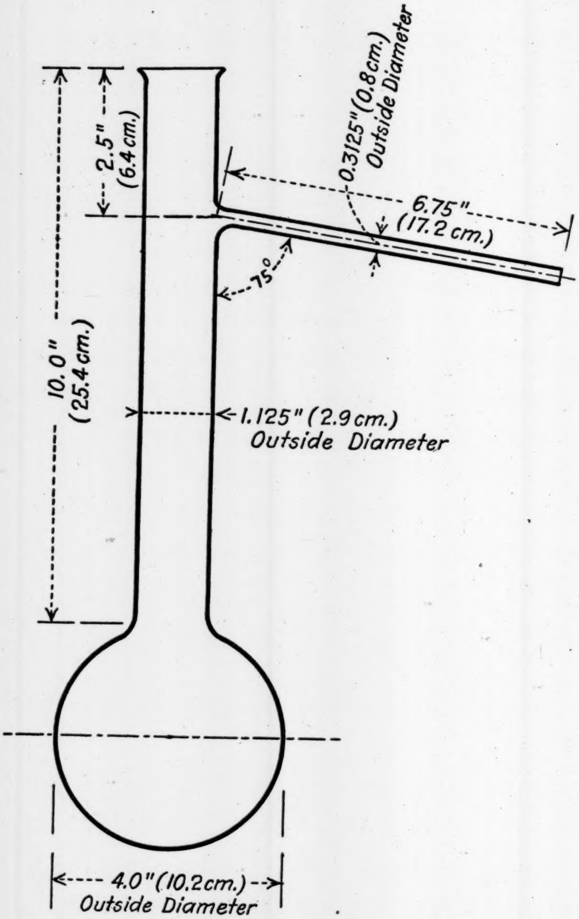
0.3125" (0.8 cm.) Outside Diameter
2.5" (6.4 cm.)
6.75" (17.2 cm.)
75°
10.0" (25.4 cm.)
1.125" (2.9 cm.) Outside Diameter
4.0" (10.2 cm.) Outside Diameter

FIG. 1—Dimensions of a 300-ml. Hempel Flask.

necessarily of nickel-chromium, about No. 18 gage. One end shall be wound in a spiral a little less than 1 in. in diameter, and the remaining wire shall be bent at right angles to the plane of the spiral and cut off at a length of about 9½ in. A small loop shall be bent into the end away from the spiral and put through a hole drilled in a strip of spring steel (see *c*, Fig. 2) or other suitable material about 0.015 in. in thickness, $\frac{3}{8}$ in. in width, and 3 in. in length, bent around a cylinder 1 in. in diameter. When allowed to expand this spring strip should hold firmly on the inside of the neck of the flask and provide a secure support for the column of chain.

Thermometer.

4. *Thermometer.*—The A.S.T.M. Low-Distillation Thermometer, conforming to the requirements specified in Section 6 of the Standard Method of Test for Distillation of Natural Gas Gasoline (A.S.T.M. Designation: D 216) of the American Society for Testing Materials[1] shall be used.

Condenser.

5. *Condenser.*—The condenser shall consist of a $\frac{9}{16}$-in. (14.29-mm.) OD No. 20 Stubbs Gage seamless brass tube, 22 in. (55.88 cm.) in length. It shall be set at an angle of 75 deg. from the perpendicular and surrounded with a cooling bath 15 in. (38.1 cm.) in length, approximately 4 in. (10.16 cm.) in width, by 6 in. (15.24 cm.) in height. The lower end of the condenser tube shall be cut off at an acute angle, and curved downward for a length of 3 in. (7.62 cm.) and slightly backward to insure contact with the wall of the graduate 1 to $1\frac{1}{4}$ in. (2.54 to 3.18 cm.) below the top of the graduate when it is in position to receive the distillate.

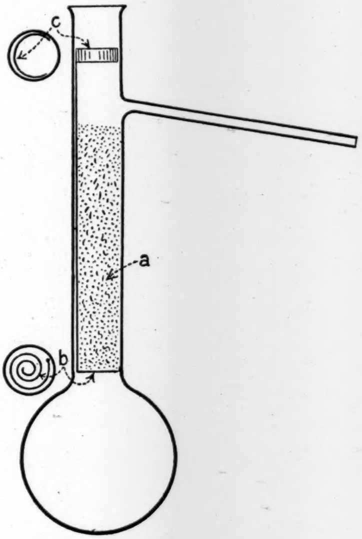

FIG. 2.—Fractionating Column and Supporting Device in a Hempel Flask.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 500.

Shield and Support.

6. *Shield and Support.*[1]—The shield shall be of any convenient type having a minimum horizontal dimension of 6 in. The flask shall rest on a board of ¼-in. (0.64-cm.) transite or hard asbestos, in the center of which is cut a hole 3½ in. (8.9 cm.) in diameter. The board shall not be less than 6 in. (15.24 cm.) in width and shall be supported by an ordinary ring stand and ring.

7. *Gas Burner or Electric Heater:*

Gas Burner.

(*a*) *Gas Burner.*—The burner shall be so constructed that sufficient heat can be obtained to distill the product at the uniform rate specified below. The flame should never be so large that it spreads over a circle of a diameter greater than 5 in. (12.7 cm.) on the under surface of the asbestos board. A sensitive regulating valve is a necessary adjunct, as it gives complete control of heating.

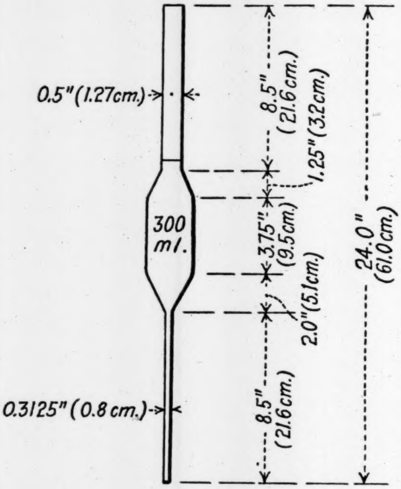

FIG. 3.—Measuring Pipette.

Electric Heater.

(*b*) *Electric Heater.*—The electric heater, which may be used in place of the gas flame, shall be capable of maintaining the distillation at the rate specified in Section 9 (*i*). The electric heater shall be fitted with an asbestos board top ⅛ to ¼ in. (3.18 to 6.35 mm.) in thickness having a hole 3½ in. (8.9 cm.) in diameter in the center. When an electric heater is employed the portion of the shield above the asbestos board shall be the same as with the gas burner, but the part below the board may be omitted.

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[1] An illustration of the condenser and of a suitable shield and support are shown in Fig. 2 of the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials, see 1930 Book of A.S.T.M. Standards, Part II, p. 491.

Graduates and Pipettes.

8. *Measuring Graduates and Pipettes.*—Filling charges and distillation fractions shall be measured with suitable accurate graduated cylinders or other volumetric glassware. A 300-ml. pipette with unconstricted outlet, similar to Fig. 3, is a convenient device for measuring charges, but an accurate graduate may be used if desired. The regular 100-ml. graduate used in gasoline distillations as specified in Section 7 of the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials[1] is reasonably satisfactory for measuring distillation fractions, but a graduate of similar dimensions that can be tightly stoppered is preferable. One can be made by cutting down a standard graduate to remove the lip and then fire polishing.

PROCEDURE

Procedure.

9. (*a*) The condenser bath shall be filled with cracked ice and sodium chloride or calcium chloride to form a freezing mixture that will cover the condenser tube and maintain a temperature between 0 and 10° F.

(*b*) The condenser tube shall be swabbed or cleaned inside to remove any liquid remaining from a previous test.

(*c*) The specific gravity of the oil to be tested shall first be determined in accordance with the Tentative Method of Test for Gravity of Petroleum and Petroleum Products by Means of the Hydrometer (A.S.T.M. Designation: D 287 – 30 T) of the American Society for Testing Materials.[2]

(*d*) A 300-ml. sample of the oil[3] shall be measured into the Hempel flask by any suitable means. For less viscous oils a pipette or graduate may be used. If the oil is decidedly viscous a sample equivalent to 300-ml. at 60° F. shall be weighed into the flask. None of the liquid shall be permitted to flow into the vapor tube.

The weight in grams of the 300-ml. sample shall then be calculated. (The weight in grams of 300 ml. of oil is equivalent to 300 times its specific gravity determined in accordance with Paragraph (*c*).)

(*e*) The supporting device for the fractionating column, Fig. 2, shall be put in place and the proper quantity of iron chain dropped in carefully so that it fills the space uniformly and without channels. Tapping the flask while the iron chain is being added is helpful, but the column shall not be compressed after all the chain is in place.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 491.

[2] See p. 1122.

[3] In case water in the crude oil causes bumping, the sample shall be dehydrated by some suitable method, without loss of naphtha, before making the determination.

(*f*) The thermometer, provided with a cork, shall be fitted tightly into the flask, so that it will be in the middle of the neck and so that the lower end of the capillary tube is about $\frac{1}{16}$ in. below the level of the inside of the bottom of the vapor tube at its junction with the neck of the flask.

(*g*) The charged flask shall be placed in position on the hard asbestos board, used with the gas burner or the electric heater and connected to the condenser with a carefully fitted cork through which the vapor tube passes. The position of the flask shall be adjusted so that the vapor tube extends into the condenser tube not less than 1 in. (2.54 cm.) nor more than 2 in. (5.08 cm.)

(*h*) A clean, dry, graduated cylinder shall be placed at the outlet of the condenser tube in such a position that the condenser tube shall extend at least 1 in. into the graduate. The graduate shall be immersed up to the level of about 1 in. below the top of the condenser tube in a transparent container of water maintained at a temperature of from 32 to 40° F. (0 to 4.4° C.). During the distillation, the top of the graduate shall be covered closely with a piece of blotting paper or its equivalent, cut to fit the condenser tube tightly.

(*i*) When everything is in readiness, heat shall be applied. The fractionating column causes some little delay between the time when the liquid starts to boil and the time the vapor enters the condenser. It is, therefore, permissible to apply heat vigorously until the liquid begins to boil, then to slow down the application of heat so that the distillate begins to come over at a moderate rate. For the first 5 to 10 ml. distilled the rate shall be from 2 to 3 ml. per minute; thereafter, the rate of distillation shall be increased to from 4 to 5 ml. per minute.

Distillation. (*j*) When the thermometer reads ....[1] the graduate shall be withdrawn from beneath the condenser and the distillation discontinued. The graduate shall be tightly stoppered and allowed to stand until all sediment and moisture have settled out and until its contents have reached a temperature between 55 and 65° F. The total volume in the graduate shall then be read and recorded as D. The volume of water, if any, shall be read and recorded as W.

The percentage of naphtha in the crude oil shall be calculated from the following formula:

$$\text{Percentage of naphtha} = \frac{D - W}{300 - W} \times 100$$

The whole procedure shall be repeated enough times to yield a total volume of distillate of not less than 100 ml.

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[1] The temperature at which the distillation shall be stopped can best be decided by mutual agreement between the parties concerned in the evaluation of a given crude petroleum.

Naphtha Distillation.

10. *Naphtha Distillation.*—The distillates shall be poured together (taking care to avoid losses by evaporation and rejecting the layers of water, if present) and shall be mixed thoroughly by shaking. A distillation test of the combined distillates shall be made in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials,[1] except that the initial boiling point shall be recorded and the volume of distillate collected in the cylinder shall be observed and recorded to the nearest 0.5 ml. when the mercury of the thermometer reaches 212° F. (100° C.), 221° F. (105° C.), 284° F. (140° C.), 392° F. (200° C.) and the end point.

ACCURACY

Accuracy.

11. Results of duplicate tests in the crude-oil distillation should not differ from each other by more than 0.5 per cent. In the naphtha distillation duplicate results obtained for initial boiling point and maximum temperature, respectively, shall not differ from each other by more than 6° F. (3.33° C.). Duplicate readings of the volume of distillate collected in the cylinder when each of the prescribed temperature points is reached should not differ by more than 2 ml.

CORRECTION FOR BAROMETRIC PRESSURE

Correction.

12. The actual barometric pressure shall be ascertained and recorded, but no correction shall be made except in case of dispute, when the temperature points shall be corrected to 760 mm. (29.92 in.) by the use of the Sydney Young Equation, as follows:

For Centigrade Readings:

$$C_c = 0.00012\ (760 - P)(273 + t_c)$$

For Fahrenheit Readings:

$$C = 0.00012\ (760 - P)(460 + t_f),$$

in which C_c and C_f are, respectively, corrections to be added to the observed temperature t_c or t_f; and P is the barometric pressure in millimeters of mercury.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 491.

TENTATIVE METHOD OF TEST
FOR
GRAVITY OF PETROLEUM AND PETROLEUM PRODUCTS BY MEANS OF THE HYDROMETER[1]

A.S.T.M. Designation: D 287 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1928; REVISED, 1930.

Scope. 1. This method covers the determination of the specific gravity and the A.P.I. gravity of crude petroleum and petroleum products normally handled as liquids. The determination of the gravity of mixtures of petroleum products with other substances is treated as a special case owing to the fact that the coefficients of expansion of such mixtures may not be the same as those of petroleum or its products. The determination of the specific gravity of road oils, road tars, asphalt cements and soft tar pitches is covered by the Standard Method of Test for Specific Gravity of Road Oils, Road Tars, Asphalt Cements and Soft Tar Pitches (A.S.T.M. Designation: D 70) of the American Society for Testing Materials[2] and the testing of these products is, therefore, specifically excluded from the scope of this method.

DEFINITIONS

Specific Gravity. 2. (*a*) *Specific Gravity.*—The specific gravity of a petroleum oil and of mixtures of petroleum products with other substances is the ratio of the weight of a given volume of the material at a temperature of 60° F. (15.56° C.) to the weight of an equal volume of distilled water at the same temperature, both weights being corrected for the buoyancy of air.

A. P. I. Gravity. (*b*) *A.P.I. Gravity.*—The A.P.I. gravity scale is an arbitrary one which is related to the specific gravity of a petroleum oil in accordance with the formula:

$$\text{Degrees A. P. I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5$$

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 664.

A table showing the equivalent specific gravity, pounds per gallon and gallons per pound at 60° F. for each degree A.P.I. from 0 to 100° A.P.I. is given in the Appendix to this method.

APPARATUS

There are two kinds of hydrometers in common use, the plain type and the combined thermometer and hydrometer, known as a thermo-hydrometer. Although the thermo-hydrometer type of instrument is sufficiently satisfactory for routine use, the thermometer incorporated in it possesses certain inherent defects of design which render it unfit for use when results of unquestioned accuracy are desired. Therefore, in all referee tests the temperature of the sample being tested must be determined by means of a separate thermometer.

Hydrometer Calibrations.

3. *Hydrometer Calibrations.*—The hydrometer may be calibrated either in terms of specific gravity or degrees A.P.I. It shall be of glass of the conventional constant mass and variable displacement type, with a paper hand-written scale printed in black ink. The range may be any suitable portion of the interval between 0 and 100° A.P.I. (1.0760 to 0.6112 sp. gr.) and it shall be so divided that 0.1° A.P.I. or 0.0005 of a unit of specific gravity shall not be less than 1 mm. (0.039 in.) in width. The value of the smallest sub-divisions shall be 0.1° A.P.I. when the instrument is calibrated in degrees A.P.I. or 0.0005 of a unit of specific gravity when it is calibrated in the specific gravity scale. The accuracy of calibration of the hydrometer shall be such that the error at any point of the scale shall not exceed the value of one smallest scale division. Each fifth smallest subdivision on the scale shall be denoted by a longer line. The graduations shall be numbered at each multiple of 1° A.P.I. or at each multiple of 0.01 of a unit of specific gravity, in accordance with the type of calibration used. The paper scale, or an extension thereof, of the hydrometer shall have plainly printed on it the name of the manufacturer, a serial number and the definition of the scale. There shall be a mark on the stem of the hydrometer corresponding to a fixed mark on the paper scale, to provide a check against possible displacement of the scale.

NOTE.—In the case of A.P.I. hydrometers the scale is defined by the expression:

$$\text{“Degrees A.P.I.} = \frac{141.5}{\text{sp. gr. } 60°/60° \text{ F.}} - 131.5\text{”}$$

In the case of specific gravity hydrometers the inscription "Sp. gr. 60°/60° F., Petroleum" is sufficient to denote that the hydrometer is intended to determine specific gravities at 60° F. relative to water at 60° F. when the readings are taken at 60° F.

The long axis of the hydrometer shall assume a vertical position when the instrument is floating freely in the sample. Any solid material, such as shot, paper, etc., used in the weighting of the hydrometer shall be firmly secured in place by the use of a suitable cement, the softening point of which lies well above 215° F. When mercury is used for weighting, it shall be placed in a small bulb below the main bulb of the hydrometer and completely separated from the bulb by means of a glass partition.

Thermometers.

4. (*a*) *Separate Thermometer.*—These specifications cover a total immersion thermometer graduated in either Fahrenheit or Centigrade degrees as specified, the ranges being −5 to +215° F. or −20 to +102° C., respectively.

TYPE: Etched stem, glass.

LIQUID: Mercury.

RANGE AND SUBDIVISION: −5 to +215° F. in 0.5° F. or −20 to +102° C. in 0.2° C.

TOTAL LENGTH: 403 to 409 mm. (15.87 to 16.10 in.).

STEM: Plain front, enamel back, suitable thermometer tubing.
Diameter 7 to 8 mm. (0.276 to 0.315 in.).

BULB: Corning normal or equally suitable thermometer glass, heavy wall.
Length 14 to 19 mm. (0.55 to 0.75 in.).
Diameter 6 to 7 mm. (0.236 to 0.275 in.).

DISTANCE TO −5° F. or −20° C. LINE FROM BOTTOM OF BULB: 32 to 51 mm. (1.26 to 2.00 in.).

DISTANCE TO +215° F. or +102° C. LINE FROM TOP OF STEM: 25 to 45 mm. (0.98 to 1.77 in.)

FILLING ABOVE MERCURY: Nitrogen gas.

TOP FINISH: Glass ring.

GRADUATIONS: All lines, figures and letters clear cut and distinct. Each whole degree Fahrenheit or Centigrade line to be longer than the remaining lines. Graduations to be numbered at each multiple of 5° F. or 2° C.

IMMERSION: Total.

SPECIAL MARKING: "A.S.T.M. Gr.," a serial number and the manufacturer's name or trade mark shall be etched on the stem.

SCALE ERROR: The error at any point of the scale when the thermometer is standardized as provided below shall not exceed 0.25° F. or 0.1° C.

STANDARDIZATION: The thermometer shall be standardized immersed in the testing bath to the top of the mercury column, at the ice point and at temperature intervals of from 30 to 40° F. or 15 to 20° C.

CASE: The thermometer shall be supplied in a suitable case on which shall appear the marking: "A.S.T.M. Gr. −5 to +215° F." or "A.S.T.M. Gr. −20 to +102° C." according to the type of thermometer.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

(*b*) *Thermometer for Thermo-hydrometer.*—The thermometer incorporated in the thermo-hydrometer type of instrument shall be of the paper scale type (scale to be placed in either the bulb or stem of the hydrometer) having a range of from 20 to 130° F. or 60 to 220° F. depending upon the range of the hydrometer. The paper temperature scale shall be graduated in 2° F. divisions accurate to ± 1° F. (Note) and, when located in the stem of the hydrometer, shall be printed in red ink to avoid any possibility of its being confused with the black gravity scale.

NOTE.—This approximates the limit of accuracy which it is possible to obtain in this type of thermometer. It becomes at once obvious, therefore, in view of the following facts, that a high degree of accuracy in the determination of the gravity of an oil can not be expected when this type of thermometer is used for the determination of the temperature of the sample undergoing test.

Between 10 and 11° A.P.I., one degree A.P.I. is equivalent to 0.0070 of a unit of specific gravity. Between 90 and 91° A.P.I., one degree A.P.I. is equivalent to only 0.0028 of a unit of specific gravity. In correcting the observed gravity of an oil of 10° A.P.I. for temperature, an error of ±2° F. in the determination of the temperature of the oil will introduce maximum error of only 0.1° A.P.I. (0.0007 sp. gr.) in the gravity. In correcting the observed gravity of an oil of 90° A.P.I. for temperature, an error of 1° F. in the determination of the temperature of the oil will introduce a maximum error of 0.3° A.P.I. (0.00084 sp. gr.) in the gravity. For convenience, the following table is given which shows the errors at each tenth degree A.P.I. from 10 to 100° A.P.I. which may be introduced into a corrected gravity as the result of an error of ±1° F. in the determination of the observed temperature:

OBSERVED GRAVITY, DEG. A.P.I.	RESULTANT MAXIMUM ERROR IN CORRECTED GRAVITY, DEG. A. P. I. PER ± 1° F. ERROR IN OBSERVED TEMPERATURE.
10–11	0.1
20–21	0.1
30–31	0.1
40–41	0.1
50–51	0.2
60–61	0.2
70–71	0.2
80–81	0.2
90–91	0.3
At 99	0.3

Hydrometer Cylinder.

5. *Hydrometer Cylinder.*—The hydrometer cylinder in which the sample for the gravity test is confined may be made of metal or clear glass and shall be cylindrical in shape. For convenience in pouring it may have a lip on the rim. The inside diameter of the cylinder shall be at least 2.54 cm. (1.0 in.) greater than the outside diameter of the hydrometer used in it. The height of the cylinder shall be such that the length of the column of sample it contains is greater by at

least 2.54 cm. (1.0 in.) than the portion of the hydrometer which is immersed beneath the surface of the sample after a state of equilibrium has been reached.

PROCEDURE

Petroleum and Petroleum Products.

6. (*a*) The determination of the gravity of crude petroleum or its products may be made at any suitable temperature between 0 and 195° F. in accordance with the procedure described in Section 7. The observed gravity at the observed temperature shall be corrected to the gravity at 60° F. as described in Section 8.

Mixtures of Petroleum with Other Substances.

(*b*) The gravity of mixtures of petroleum products with other substances shall be determined at a temperature of 60° F. in accordance with the procedure described in Section 7, since there are no nationally recognized tables giving the coefficients of expansion of such mixtures.

Procedure.

7. The sample to be tested for gravity shall be poured into the clean hydrometer cylinder without splashing, so as to avoid the formation of air bubbles and to reduce to a minimum the evaporation of the lower boiling constituents of the lighter oils. If air bubbles are formed they shall be removed after they have collected on the surface, by touching them with a piece of clean blotting paper or filter paper before the hydrometer is placed in the sample. If the sample to be tested is easily volatile both the hydrometer and hydrometer cylinder shall be cooled before use to a temperature below that of the sample.

The cylinder containing the prepared sample shall be placed in a vertical position in a place free from air currents. The hydrometer shall be carefully lowered into the sample to a level two smallest scale divisions below that at which it will float and shall then be released. When the hydrometer has come to rest, floating freely away from the walls of the cylinder, the gravity shall be read as the point at which the surface of the sample apparently cuts the hydrometer scale. In the case of samples sufficiently transparent this point shall be determined by placing the eye slightly below the level of the liquid and slowly raising it until the surface of the sample first seen as a distorted ellipse seems to become a straight line cutting the hydrometer scale. In the case of non-transparent samples where this procedure cannot be followed, the point on the hydrometer scale to which the sample rises above the main surface of the liquid shall be read with the eye placed slightly above the plane of the surface of the sample. This reading shall then be corrected by subtracting in the case of A.P.I. hydrometers or adding in the case of specific-gravity hydrometers, an amount equal to the height which the sample rises on the hydrometer stem above the main liquid surface. This height will vary for different oils and different hydrometers and the amount of correction necessary will depend upon the width of the hydrometer scale graduations. The necessary correction factor shall be determined, therefore, for the particular hydrometer in use by observing the height above the main surface of the liquid to which the oil rises on the hydrometer scale when the hydrometer in question is immersed in a transparent oil having a surface tension similar to that of the sample under test.

NOTE.—In the routine testing of opaque crude petroleum with the usual type of hydrometer with a 12-deg. range, it is customary and permissible to correct the reading taken as prescribed above for non-transparent samples by an arbitrary deduction of 0.1° A.P.I. from the observed gravity reading.

The temperature of the sample shall be determined from the reading of the separate thermometer placed in the sample or from that of the thermometer contained in the hydrometer when the thermo-hydrometer type of instrument is used (see Note).

NOTE.—Precautions should, of course, be taken to prevent the temperature of the sample from changing appreciably during the time necessary to complete the test. This may be done when testing non-viscous oils by choosing a temperature of test only slightly different from the room temperature. When testing viscous oils which must be heated before testing it will be necessary to surround the test cylinder with a bath maintained at a constant desired temperature during the time of test.

Although it is usually satisfactory to determine the temperature of the sample immediately after reading the hydrometer, it is recommended that in all referee tests this temperature be determined both before and after the hydrometer is read.

CALCULATION

Calculation.

8. In the case of crude petroleum and petroleum products the determinations made in Section 7 are commonly referred to as "observed gravity and observed temperature." These observations shall be corrected to the gravity at 60° F. by the use of Tables 1 and 3 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No. 154*. Table 1 shall be employed if the observed gravity is in degrees A.P.I. and Table 3 if expressed as specific gravity.

Interpolations in Table 1 shall be made as follows: When the observed gravity ends in 1, 2, 3, 4 or 5 tenths of a degree A.P.I., find the degrees A.P.I. at 60° F. corresponding to the observed gravity, disregarding the tenths of a degree. To this value add tenths of a degree dropped from the observed gravity to obtain the corrected value of the gravity in degrees A.P.I. at 60° F. When the observed gravity ends in 6, 7, 8 or 9 tenths find the degrees A.P.I. at 60° F. corresponding to the next larger value of observed gravity in the table. Correct this figure by subtracting a number of tenths equal to the difference between the observed value and the next larger value.

ACCURACY

Duplicate Determinations.

9. Duplicate determinations shall agree within 0.1° A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined when the same hydrometer and thermometer are used in the tests.

Separate laboratories using different hydrometers and thermometers should obtain duplicate results agreeing within 0.5° A.P.I. or the equivalent thereof in units of specific gravity at the particular gravity being determined.

APPENDIX

The following table is primarily an abridgement of Table 5 of the "National Standard Petroleum Oil Tables" as published in the U. S. Bureau of Standards *Circular No. 154,* which contains similar data for each 0.1° A.P.I. from 10 to 100° A.P.I., inclusive. The data for gravities from 0 to 9° A.P.I., inclusive, have been added in order to extend the use of the A.P.I. gravity scale to petroleum oils having a specific gravity slightly greater than unity.

TABLE SHOWING SPECIFIC GRAVITIES, POUNDS PER GALLON, AND GALLONS PER POUND AT 60° F., CORRESPONDING TO DEGREES A.P.I.

Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.[1]	Gallons per Pound at 60° F.[1]	Degrees A. P. I.	Specific Gravity at 60°/60° F.	Pounds per Gallon at 60° F.[1]	Gallons per Pound at 60° F.[1]
0	1.0760	8.962	0.1116	50	0.7796	6.490	0.1541
1	1.0679	8.895	0.1124	51	0.7753	6.455	0.1549
2	1.0599	8.828	0.1133	52	0.7711	6.420	0.1558
3	1.0520	8.762	0.1141	53	0.7669	6.385	0.1566
4	1.0443	8.698	0.1150	54	0.7628	6.350	0.1575
5	1.0366	8.634	0.1158	55	0.7587	6.316	0.1583
6	1.0291	8.571	0.1167	56	0.7547	6.283	0.1592
7	1.0217	8.509	0.1175	57	0.7507	6.249	0.1600
8	1.0143	8.448	0.1184	58	0.7467	6.216	0.1609
9	1.0071	8.388	0.1192	59	0.7428	6.184	0.1617
10	1.0000	8.328	0.1201	60	0.7389	6.151	0.1626
11	0.9930	8.270	0.1209	61	0.7351	6.119	0.1634
12	0.9861	8.212	0.1218	62	0.7313	6.087	0.1643
13	0.9792	8.155	0.1226	63	0.7275	6.056	0.1651
14	0.9725	8.099	0.1235	64	0.7238	6.025	0.1660
15	0.9659	8.044	0.1243	65	0.7201	5.994	0.1668
16	0.9593	7.989	0.1252	66	0.7165	5.964	0.1677
17	0.9529	7.935	0.1260	67	0.7128	5.934	0.1685
18	0.9465	7.882	0.1269	68	0.7093	5.904	0.1694
19	0.9402	7.830	0.1277	69	0.7057	5.874	0.1702
20	0.9340	7.778	0.1286	70	0.7022	5.845	0.1711
21	0.9279	7.727	0.1294	71	0.6988	5.817	0.1719
22	0.9218	7.676	0.1303	72	0.6953	5.788	0.1728
23	0.9159	7.627	0.1311	73	0.6919	5.759	0.1736
24	0.9100	7.578	0.1320	74	0.6886	5.731	0.1745
25	0.9042	7.529	0.1328	75	0.6852	5.703	0.1753
26	0.8984	7.481	0.1337	76	0.6819	5.676	0.1762
27	0.8927	7.434	0.1345	77	0.6787	5.649	0.1770
28	0.8871	7.387	0.1354	78	0.6754	5.622	0.1779
29	0.8816	7.341	0.1362	79	0.6722	5.595	0.1787
30	0.8762	7.296	0.1371	80	0.6690	5.568	0.1796
31	0.8708	7.251	0.1379	81	0.6659	5.542	0.1804
32	0.8654	7.206	0.1388	82	0.6628	5.516	0.1813
33	0.8602	7.163	0.1396	83	0.6597	5.491	0.1821
34	0.8550	7.119	0.1405	84	0.6566	5.465	0.1830
35	0.8498	7.076	0.1413	85	0.6536	5.440	0.1838
36	0.8448	7.034	0.1422	86	0.6506	5.415	0.1847
37	0.8398	6.993	0.1430	87	0.6476	5.390	0.1855
38	0.8348	6.951	0.1439	88	0.6446	5.365	0.1864
39	0.8299	6.910	0.1447	89	0.6417	5.341	0.1872
40	0.8251	6.870	0.1456	90	0.6388	5.316	0.1881
41	0.8203	6.830	0.1464	91	0.6360	5.293	0.1889
42	0.8155	6.790	0.1473	92	0.6331	5.269	0.1898
43	0.8109	6.752	0.1481	93	0.6303	5.246	0.1906
44	0.8063	6.713	0.1490	94	0.6275	5.222	0.1915
45	0.8017	6.675	0.1498	95	0.6247	5.199	0.1924
46	0.7972	6.637	0.1507	96	0.6220	5.176	0.1932
47	0.7927	6.600	0.1515	97	0.6193	5.154	0.1940
48	0.7883	6.563	0.1524	98	0.6166	5.131	0.1949
49	0.7839	6.526	0.1532	99	0.6139	5.109	0.1957
				100	0.6112	5.086	0.1966

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[1] The data in this column are based upon apparent weights in air, the weight of one gallon of water at 60° F. in air being assumed to be 8.32828 lb. Consequently, a correction for the buoyancy of air is required in computing these figures from the specific gravities in the second column.

TENTATIVE METHOD OF TEST
FOR
PRECIPITATION NUMBER OF LUBRICATING OILS[1]

A.S.T.M. Designation: D 91 - 30 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1929, 1930.

Scope. 1. This method is commonly used for steam cylinder stocks and black oils and may be used for other lubricating oils.

DEFINITION

Definition. 2. *A.S.T.M. Precipitation Number of Lubricating Oils.*—The number of milliliters of precipitate formed when 10 ml. of lubricating oil are mixed with 90 ml. of petroleum naphtha as specified in Section 5 and centrifuged under prescribed conditions.

APPARATUS

Centrifuge. 3. *Centrifuge.*—The centrifuge shall be capable of whirling at least two 100-cc. centrifuge tubes filled with water at the required speed. It shall be of sound design and rugged construction so that it may be operated without danger. The tube carriers shall be so designed that the glass centrifuge tubes may be cushioned with water, rubber or other suitable material. The tube holders shall be surrounded during the operation by a suitable metal shield or case, strong enough to eliminate danger if any breakage occurs.

Preferred forms of centrifuge shall have a diameter of swing (tip to tip of whirling tubes) of 15 to 17 in. and a speed of at least 1500 r.p.m. or equivalent. If the available centrifuge has a diameter of swing varying from these limits, it shall be run at the proper speed to give the same centrifugal force at the tips of the tubes as that obtained with the preferred form of centrifuge. The proper speed shall be calculated from the following formula in which D represents the diameter of swing (tip to tip of whirling tubes) of the centrifuge used:

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

$$\text{Revolutions per minute} = 1500\sqrt{\frac{16}{D}}$$

Centrifuge Tubes. 4. The centrifuge tube, A.S.T.M. cone-shaped type shown in Fig. 1, shall be made of suitable glass and thoroughly annealed. The total capacity shall be about 125 ml. and the mouth shall be suitably constricted for closing with a cork. The graduations shall be clear and distinct, reading upward from the bottom of the tube. The length and outside diameter are optional provided they do not conflict with the other requirements. The value of the divisions for each range with limits of error are given in the following tabulation:

RANGE	SCALE DIVISION	LIMIT OF ERROR	NUMBERED
0 to 0.1 ml.	0.05 ml.	0.02 ml.	......
0.1 to 0.3 "	0.05 "	0.03 "	......
0.3 to 0.5 "	0.05 "	0.05 "	½ ml.
0.5 to 1.0 "	0.1 "	0.05 "	1 "
1 to 3 "	0.1 "	0.1 "	2, 3 "
3 to 5 "	0.5 "	0.2 "	4, 5 "
5 to 10 "	1.0 "	0.5 "	6, 8, 10 "
10 to 25 "	5.0 "	1.0 "	15, 20, 25 "
25 to 100 "	25.0 "	1.0 "	50, 75, 100"

Thermometer. 5. The A.S.T.M. aniline point thermometer shall be identical with the A.S.T.M. paraffin wax melting point thermometer described in Section 6 of the Standard Method of Test for Melting Point of Paraffin Wax (A.S.T.M. Designation: D 87) of the American Society for Testing Materials.[1]

Diluent. 6. (*a*) Petroleum naphtha conforming to the following requirements shall be used for the diluent.

Gravity, deg. A.P.I. at 60° F.	**70 to 73**
Aniline Point, deg. Centigrade	**58 to 60**
Initial Boiling Point, A.S.T.M.	**not less than 122° F. (50° C.)**
50-per-cent point, A.S.T.M.	**158 to 176° F. (70 to 80° C.)**
End Point, A.S.T.M.	**not more than 266° F. (130° C.)**

(*b*) The initial boiling point, the 50-per-cent point, and the end point of the petroleum naphtha shall be determined in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[2]

(*c*) The aniline point of the petroleum naphtha shall be determined as follows: Measure 10 ml. of the sample and 10 ml. of the aniline(freshly distilled, free from aminothiophenes) into a large test tube fitted with a stirrer and a thermometer. Heat the mixture by means of a naked flame until it becomes homogeneous, and then allow to cool until it becomes turbid. Raise the temperature slightly and make a duplicate determination. Disregard any slight initial turbidity, taking the temperature when the solution becomes completely cloudy. If the aniline point is more than 10° C. above the room temperature, use another larger test tube to form an air jacket.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 527.

[2] *Ibid.*, p. 491.

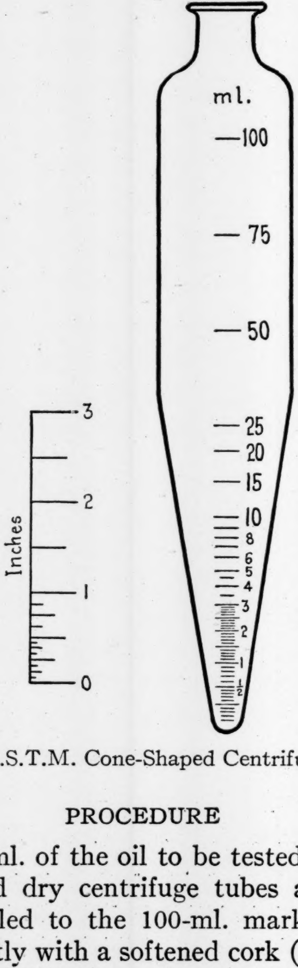

FIG. 1.—A.S.T.M. Cone-Shaped Centrifuge Tube.

PROCEDURE

Preparing for Centrifuging

7. Exactly 10.0 ml. of the oil to be tested shall be measured in each of two clean and dry centrifuge tubes at room temperature. Each tube shall be filled to the 100-ml. mark with the prescribed diluent and closed tightly with a softened cork (not a rubber stopper). Each tube shall then be inverted at least 20 times, allowing the liquid to drain thoroughly from the tapered tip of the tube each time. The tubes shall then be placed in a water bath at 90 to 95° F. for five

minutes. The corks shall be momentarily removed to relieve any pressure and each tube shall again be inverted at least 20 times exactly as before. The success of this method depends to a large degree upon having a thoroughly homogeneous mixture which will drain quickly and completely from the tapered tip when the tube is inverted.

Centrifuging.

8. The two centrifuge tubes shall then be placed in the centrifuge on opposite sides and shall be whirled at a rate of 1400 to 1500 r.p.m. or equivalent for 10 minutes. The volume of sediment at the bottom of each tube shall be read and recorded, estimating to 0.05 ml. if possible. The tubes shall then be replaced in the centrifuge, again whirled for 10 minutes as before, and removed for reading the volume of the sediment as before. This operation shall be repeated until the volume of sediment in each tube remains constant for three consecutive readings. In general, not more than four whirlings are required for oils having a low precipitation number.

Precipitation Number.

9. The volume of the solid sediment at the bottom of each centrifuge tube shall be read, estimating to 0.1 ml. or closer if possible. If the two readings differ by not more than 0.1 ml. the mean of the two shall be reported as the "A.S.T.M. Precipitation Number." If the two readings differ by more than 0.1 ml. two more determinations shall be made and the average of the four determinations shall be reported.

ACCURACY

Accuracy.

10. With care and proper attention to details, duplicate determinations of precipitation number by this method should not differ by more than 0.1 ml., provided the centrifuge tubes are accurate and readable to this degree.

TENTATIVE METHOD OF TEST
FOR
SULFUR IN MOTOR FUELS, NAPHTHAS AND ILLUMINATING OILS (LAMP METHOD)[1]

A.S.T.M. Designation: D 90 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1924, 1926, 1929, 1930.

Scope. 1. This method is intended to cover the determination of sulfur in gasolines and other volatile motor fuels, in illuminating oils, and in petroleum naphthas. It is not strictly applicable to mixtures containing carbon bisulfide.

NOTE.—When this method is applied to mixtures containing carbon bisulfide approximately 85 per cent of the sulfur present as carbon bisulfide is usually determined.

APPARATUS

Apparatus. 2. The apparatus shall consist of the following:

(*a*) *Absorber.*—An absorber of chemically-resistant glass conforming to the dimensions shown in Fig. 1. The larger of the two bulbs of the absorber shall be filled at least two-thirds full with pieces of chemically-resistant glass rod from 8 to 10 mm. in length and from 5 to 6 mm. in diameter, or with perforated beads of chemically resistant glass 5 to 8 mm. in diameter.

(*b*) *Chimney.*—A chimney of chemically-resistant glass conforming to the dimensions shown in Fig. 1, and connected with the absorber by a cork stopper.

(*c*) *Spray Trap.*—A spray trap of chemically-resistant glass conforming to the dimensions shown in Fig. 1, and connected with the absorber by a cork or by a rubber stopper.

(*d*) *Lamp.*—A small lamp of about 25-ml. capacity. The lamp may conveniently consist of a 25 to 35-ml. Erlenmeyer flask, preferably of the dimensions shown in Fig. 1, and a cork carrying a piece of

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

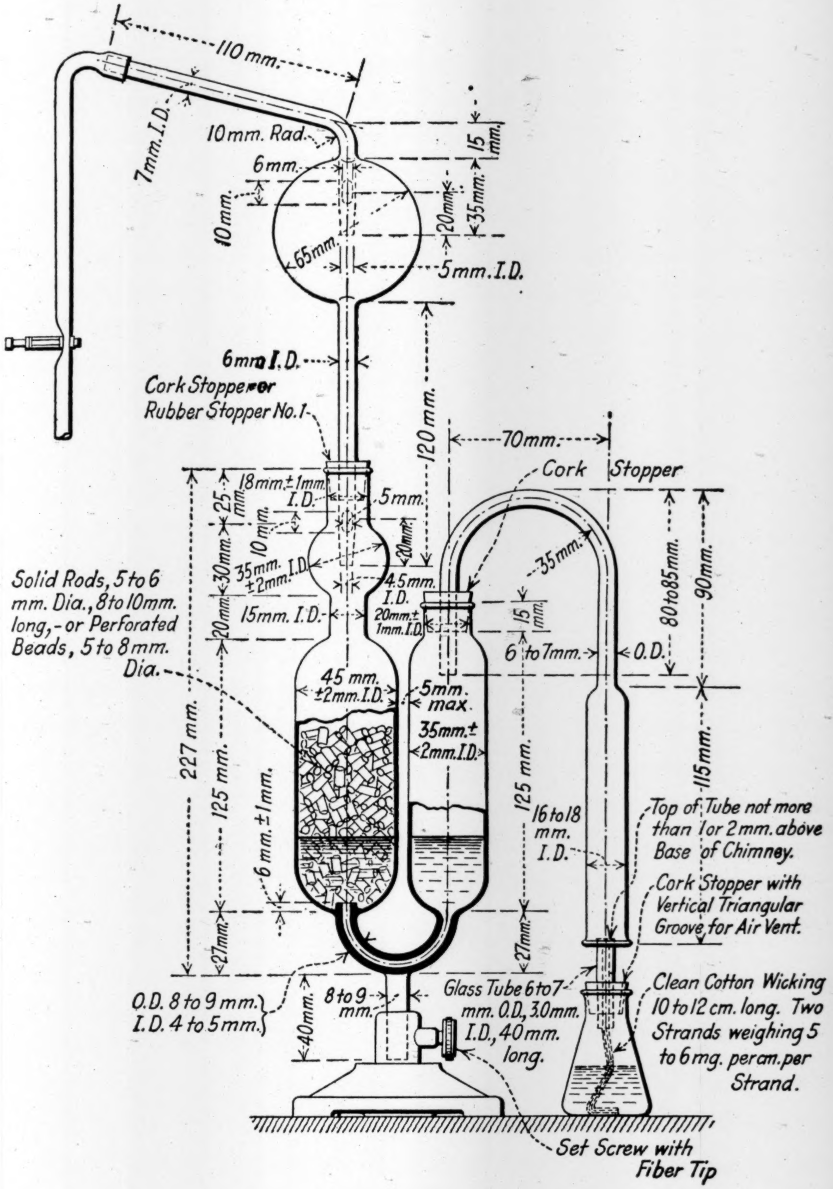
110 mm.
7mm. I.D.
10mm. Rad.
15 mm.
6mm.
35mm.
10mm.
20mm.
65mm.
5mm. I.D.
6mm I.D.
Cork Stopper or
Rubber Stopper No. 1
120 mm.
70mm.
Cork Stopper
18mm.±1mm. I.D.
25 mm.
5mm.
10 mm.
20mm.
35mm.
30mm.
35mm. ±2mm. I.D.
4.5mm. I.D.
15 mm.
Solid Rods, 5 to 6 mm. Dia., 8 to 10mm. long, - or Perforated Beads, 5 to 8 mm. Dia.
20mm.
15mm. I.D.
20mm.± 1mm. I.D.
80 to 85 mm.
90mm.
6 to 7mm.
O.D.
45 mm. ±2mm. I.D.
5mm. max.
35mm.± 2mm. I.D.
227 mm.
125 mm.
6 mm.±1mm.
125 mm.
16 to 18 mm. I.D.
115mm.
Top of Tube not more than 1 or 2 mm. above Base of Chimney.
Cork Stopper with Vertical Triangular Groove for Air Vent.
27mm.
27mm.
O.D. 8 to 9 mm.
I.D. 4 to 5 mm.
40mm.
8 to 9 mm.
Glass Tube 6 to 7 mm. O.D., 3.0mm. I.D., 40 mm. long.
Clean Cotton Wicking 10 to 12 cm. long. Two Strands weighing 5 to 6 mg. per cm. per Strand.
Set Screw with Fiber Tip

FIG. 1.—Apparatus for Determination of Sulfur in Oils.

NOTE.—In the case of those dimensions for which no specific tolerances are designated above, the permissible variation is ± 10 per cent to the nearest millimeter, provided, however, that in no case the deviation be greater than 5 mm.

glass tubing 40 mm. in length, from 6 to 7 mm. in outside diameter, and 3 mm. in inside diameter, with ends ground or fused level. The wick tube should project above the cork at least 10 mm., and the cork shall have a vertical groove in its side so that air may enter the flask to replace the oil as it is consumed.

(*e*) *Cotton Wicking.*—Two strands of clean, unused cotton wicking, 10 to 12 cm. in length and weighing about 5 to 6 mg. per cm. per strand.

(*f*) *Filter Pump.*—A filter pump or other means for continuous suction.

SOLUTIONS REQUIRED

Solutions Required.

3. (*a*) *Hydrochloric Acid.*—Prepare a solution of HCl in distilled water which will contain 2.275 g. of HCl per liter and check carefully for accuracy.

(*b*) *Sodium Carbonate.*—Dissolve 3.306 g. of Na_2CO_3 in one liter of distilled water. Ten cubic centimeters of this solution should neutralize exactly 10 ml. of the HCl solution.

(*c*) *Methyl Orange.*—Dissolve 0.004 g. of methyl orange in one liter of distilled water.

PROCEDURE

Procedure.

4. The sulfur shall be determined as follows:

(*a*) Pass two strands of the new cottom wicking through the wick tube so that they are not twisted but are parallel in the wick tube. Pour into the clean, dry lamp about 15 ml. of the oil to be tested, and insert the cork containing the wick tube. After the wick has become saturated with the oil, trim it off as nearly as possible to the top of the wick tube with a pair of sharp scissors, finally adjusting the wick height by touching the top of it with the tip of a finger. Weigh the oil and lamp assembly to the nearest 0.001 g. Run a blank determination at the same time and under the same conditions by burning sulfur-free alcohol in a similar lamp. Thoroughly rinse out the absorber with distilled water, and put into it exactly 10 ml. of the sodium carbonate solution from an accurately calibrated pipette, and then dilute the solution with 10 ml. of distilled water. Rinse out also the chimney and the spray trap with distilled water, dry the chimney, and connect both to the absorber as shown in Fig. 1. Prepare the apparatus for the blank determination in the same manner putting into it exactly 10 ml. of the sodium carbonate solution and 10 ml. of distilled water. Apply gentle suction to both absorbers; light both the oil lamp and the alcohol lamp and then place them in position under the chimneys so that the top of each wick tube extends into the chimney not more than 1 or 2 mm. above the edge. Use a sulfur-free flame, such as an alcohol lamp for lighting the lamps; do not use matches. Adjust the suction so that a steady flame 12 to 18 mm. in height and free from smoking is obtained (Note 1). The suction shall be adjusted so that air is drawn through both absorbers at approximately the same rate. The maintenance of proper flame height usually requires that the wick be flush with the top of the wick tube for naphthas or motor fuels and a little higher for illuminating oils. The room shall be free from draughts. Continue burning for from one to one and one-half hours, or less if the sulfur content of the oil is high. During this time the oil should be consumed at the rate of about 2 to 2.5 g. per hour.

(*b*) Extinguish the flames and stop the suction on both absorbers. Weigh the oil lamp immediately to the nearest 0.001 g., and determine by difference the weight of oil consumed. Working with the blank first, disconnect the spray trap and chimney and wash them thoroughly with the methyl orange solution, using a wash bottle with a very fine jet and collecting the washings in the absorber. Use approximately 35 ml. of the solution for washing. Carefully titrate the faintly-yellow solution with the HCl solution. During titration, carefully agitate the contents of the absorber either by alternate sucking and blowing through a rubber tube held between the lips, or else by the use of a suitable rubber-syringe bulb. As the end point is approached, draw the liquid back and forth between the bulbs after each addition of acid, agitating as before. When the first permanent pink color appears, the end point has been reached. Read and record the volume of HCl solution used (Note 2).

(*c*) Rinse the chimney and the spray trap used in the actual determination into the absorber to which they were connected, exactly as has been prescribed for the blank. If at this point the solution in the absorber should have a pink color, too much oil has been burned and the determination shall be repeated, but burning for a shorter time. The temporary pink color that sometimes appears in the chimney when rinsing it out should be disregarded. Titrate just as in the blank, continuing to add the HCl solution until the color matches that obtained in the blank. Read and record the volume of HCl solution used.

NOTE 1.—If it is not possible to obtain a good flame free from smoking, as sometimes happens if the oil contains considerable percentages of benzol, dilute the oil with an equal weight of sulfur-free anhydrous alcohol before putting the sample into the lamp. If, while maintaining the specified flame height the flame still smokes, a smaller flame is permissible. In order to get the correct value when calculating the percentage of sulfur present in this case, allowance shall be made for the fact that the sample as burned in the lamp is one-half alcohol. This shall be done by doubling the percentage of sulfur obtained in computation by the formula given in Section 5.

NOTE 2.—For accurate work, conditions shall be such that a minimum or zero blank is obtained. If the titration of the blank requires more than 0.1 ml. of the HCl solution per gram of sample burned, which corresponds to 0.01 per cent of sulfur, a high degree of accuracy cannot be expected in the case of oils of low sulfur content.

Calculation. 5. Calculate the sulfur content of the oil by substituting the proper values in the following formula:

$$\text{Percentage of sulfur} = \frac{\begin{matrix}\text{milliliters} \\ \text{of HCl for blank}\end{matrix} - \begin{matrix}\text{milliliters} \\ \text{of HCl for sample}\end{matrix}}{\text{grams of oil burned} \times 10}$$

This formula is correct only for the standard solutions specified in Section 3, 1 ml. of each being equivalent to 0.001 g. of sulfur. The use of solutions of any other strength, such as 0.1 *N*, involves more complicated calculation and is not advisable.

Check Determination. 6. As a check on the determination, a sample of known sulfur content shall be analyzed. Such a reference sample may be made by adding a pure volatile sulfur compound, such as carbon bisulfide, to sulfur-free anhydrous alcohol. This check shall indicate from 85 to 100 per cent of the sulfur present.

Accuracy. 7. Duplicate determinations by the same operator should not differ by more than the amounts given in the following tabulation:

SULFUR FOUND, PER CENT	AVERAGE DEVIATION FROM MEAN, PER CENT SULFUR
Under 0.125	0.0025
0.125 to 0.25	0.005
0.25 to 0.50	0.01
Over 0.50	0.02

For different operators corresponding deviations may be double those given above.

TENTATIVE METHOD OF TEST

FOR

VAPOR PRESSURE OF NATURAL GASOLINE (REID METHOD)[1]

A.S.T.M. Designation: D 323 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope.

1. This method is intended for the determination of the vapor pressure of natural gasoline.

APPARATUS

Vapor-Pressure Bomb.

2. The vapor-pressure bomb consisting of two sections or chambers, an upper section or air chamber and a lower section or gasoline chamber, shall conform to the following requirements:

(*a*) *Air Chamber.*—The upper section, or air chamber, shall be a cylindrical vessel 2 in. in diameter and approximately 10 in. in length, inside dimensions. It may be made of standard 2-in. brass or iron pipe. A $\frac{1}{4}$-in. gage coupling shall be welded into the center of one end and a $\frac{3}{4}$ by $\frac{1}{2}$-in. bushing tapped and screwed into the center of the other end. See Fig. 1 (*a*) for exact dimensions. The chamber must drain completely from either end when held in a vertical position.

(*b*) *Gasoline Chamber for Sampling Materials at Atmospheric Pressure.*—The lower section, or gasoline chamber, shall be a cylindrical vessel 2 in. in diameter and $2\frac{1}{2}$ in. in length, inside dimensions. The gasoline chamber shall have a $\frac{3}{4}$ by $\frac{1}{2}$-in. bushing tapped and screwed into the upper end. The other end of the chamber shall be completely closed (see Fig. 1 (*a*)). A $\frac{1}{2}$ by 2-in. nipple shall be used for connecting the two sections. This nipple shall be permanently attached to either the air chamber or gasoline chamber.

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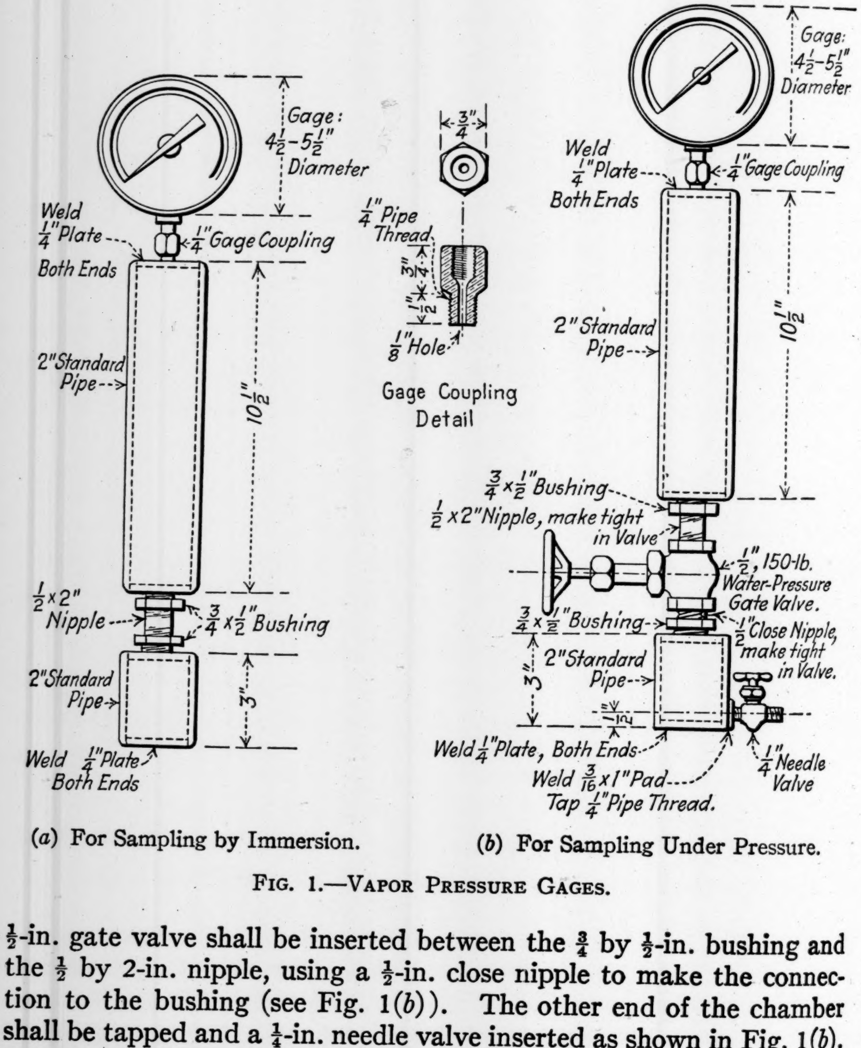
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. R. P. Anderson, Secretary of Committee D-2 on Petroleum Products and Lubricants, 250 Park Ave., New York City.

This method is essentially the same as that contained in the appendix of the 1930 revision of the Interstate Commerce Commission Regulations for the Transportation of Explosives and Other Dangerous Articles by Freight and Express and in Baggage Service.

(c) *Gasoline Chamber for Sampling Materials Under Pressure.*—For testing natural gasoline held in pressure storage or being transported by pipe line where it is impracticable to obtain a sample by immersing the gasoline chamber in the liquid, the gasoline chamber shall conform to the requirements specified in Paragraph (*b*) but a $\frac{1}{2}$-in. gate valve shall be inserted between the $\frac{3}{4}$ by $\frac{1}{2}$-in. bushing and the $\frac{1}{2}$ by 2-in. nipple, using a $\frac{1}{2}$-in. close nipple to make the connection to the bushing (see Fig. 1(*b*)). The other end of the chamber shall be tapped and a $\frac{1}{4}$-in. needle valve inserted as shown in Fig. 1(*b*). The two sections shall be connected by screwing the $\frac{1}{2}$-in. nipple on the gasoline chamber into the $\frac{3}{4}$-in. bushing on the air chamber. The $\frac{1}{2}$-in. nipple shall be permanently attached to the $\frac{1}{2}$-in. gate valve.


Gage: 4½-5½" Diameter
Weld ¼" Plate Both Ends
¼" Gage Coupling
2" Standard Pipe
10½"
½×2" Nipple
¾×½" Bushing
2" Standard Pipe
3"
Weld ¼" Plate Both Ends
¾"
¼" Pipe Thread
¾"
½"
⅛" Hole
Gage Coupling Detail
Gage: 4½-5½" Diameter
Weld ¼" Plate Both Ends
¼" Gage Coupling
2" Standard Pipe
10½"
¾×½" Bushing
½×2" Nipple, make tight in Valve
½", 150-lb. Water-Pressure Gate Valve.
¾×½" Bushing
½" Close Nipple, make tight in Valve.
2" Standard Pipe
3"
½
Weld ¼" Plate, Both Ends
Weld 3/16×1" Pad Tap ¼" Pipe Thread.
¼" Needle Valve

(*a*) For Sampling by Immersion. (*b*) For Sampling Under Pressure.

FIG. 1.—VAPOR PRESSURE GAGES.

Pressure Gage. 3. The pressure gage shall be a standard Bourdon type spring gage $4\frac{1}{2}$ to $5\frac{1}{2}$ in. in diameter. The range of the gage used shall be governed by the vapor pressure of the sample being tested, as follows: For those samples with a vapor pressure not in excess of 12 lb. per sq. in. absolute at 100° F. the gage shall have a 15-lb. scale. For those samples whose vapor pressures are between 12 and 45 lb. per sq. in. absolute at 100° F., the upper limit of the scale of the gage shall not be less than 45 nor more than 60 lb. Gages shall be checked frequently and adjusted if found in error.

Water Bath. 4. The water bath shall be of such dimensions that the vapor-pressure bomb may be immersed to the bottom of the pressure gage. Means for maintaining the bath at a constant temperature of 100° F. ± 0.5° F. should be provided.

Connections. 5. (*a*) All permanent connections may be made tight by soldering or tinning.

(*b*) Special threads or other suitable means may be used in making the connection between the two chambers in order to obtain a tight connection without the use of a wrench.

PROCEDURE

Filling the Gasoline Chamber. 6. (*a*) *Sampling Tank Cars and Open Tanks.*—The empty gasoline chamber, Fig. 1 (*a*), shall first be immersed in the tank or container of the liquid to be tested and allowed to fill while being raised and lowered through the liquid. This first filling is for the purpose of thoroughly washing the chamber, which should then be emptied. The chamber shall then be refilled in the same manner, care being exercised to see that it is completely filled with the liquid.

(*b*) *Sampling Systems Under Pressure.*—The gasoline chamber equipped with valves, top and bottom, Fig. 1(*b*), shall be used.

Before drawing the sample, the liquid section of the gasoline chamber shall be cooled to a temperature as low as or lower than that of the gasoline to be tested. The sample shall be taken as follows:

Close both valves and connect the gasoline chamber to the tank, pipe line, or other receptacle holding the liquid to be tested, by means of the lower valve of the chamber. The sample must be taken at a place which will ensure that a representative sample of the gasoline is being obtained.

With the upper valve closed, open the valve on the tank or pipe line and then open the lower valve on the gasoline chamber, allowing full tank or line pressure to be exerted on the chamber. Open slightly the upper valve of the chamber and allow gasoline to escape until a volume equal to at least twice the capacity of the gasoline chamber shall have been displaced. This procedure insures the removal of all air from the chamber. The operation of purging should be accomplished without allowing the pressure in the chamber to drop below that of the tank or line. After filling the gasoline chamber, close both top and bottom valves in the order mentioned, and disconnect the chamber from the tank or pipe line. After disconnecting the gasoline chamber, attach it to the air chamber immediately; otherwise the gasoline chamber should be kept chilled in order to prevent rupturing it due to expansion of the contents.

(*c*) *Sampling by Pouring.*—A sample shall not be transferred to the gasoline chamber by pouring unless it is impossible to obtain it by either of the methods described in Paragraphs (*a*) and (*b*). When this is the case both the liquid and the gasoline chamber shall be cold enough so that no appreciable change in composition of the sample occurs during the pouring. Table I gives the maximum pouring temperatures for gasolines of various vapor pressures. The responsibility for errors incurred by pouring rests solely with the operator. Pouring shall not be used in referee tests.

TABLE I.—TEMPERATURE TO WHICH GASOLINE SHALL BE COOLED BEFORE POURING.

VAPOR PRESSURE LB. PER SQ. IN. ABSOLUTE, AT 100° F.	TEMPERATURE OF SAMPLE AND CHAMBER WHEN POURING, DEG. FAHR.
9 or under	32 to 40
9 to 12	15 to 20
12 to 16	10 to 15

(*d*) *Sampling by Water Displacement.*—It is recommended that transfer by water displacement be used when the methods described in Paragraphs (*a*), (*b*) and (*c*) cannot be employed.

Procedure. 7. Prior to each test the air chamber shall be thoroughly purged of any gasoline or gasoline vapors that may remain from a previous test. The purging may best be accomplished by filling the air chamber, from which the gage has been removed, with hot water (90 to 100° F.) and allowing it to drain. This operation shall be repeated at least five times. If the bomb is purged some time before the test is made, it should again be rinsed with water (temperature optional) just before the test is started. The temperature of the air and water vapor in the air chamber shall be determined by inserting a standard thermometer of suitable range inside the chamber just before making the connection with the gasoline chamber. At least one minute shall be allowed for this reading, which shall be recorded. After taking this temperature, the air chamber with the gage in place shall then immediately be attached tightly to the gasoline chamber, using a little shellac or other suitable sealing material on the threads, if necessary, to make a tight connection. In using the gasoline chamber equipped with valves, the upper valve shall be opened immediately. The vapor-pressure bomb shall then be turned upside down several times to allow gasoline to run into the air chamber. It shall then be immersed in the water bath held at a constant temperature of 100°F. ± 0.5° F. After 5 minutes the bomb shall be withdrawn from the bath, inverted, shaken vigorously, and replaced in the bath. This operation shall be repeated as quickly as possible at intervals of 2 minutes until the gage reading becomes constant, with the bomb in the bath. The gage should be tapped lightly prior to each reading. All connections shall be closely observed and if any leaks are detected the test shall be discarded.

TABLE II.—CORRECTION FACTORS FOR INCREASE IN AIR AND WATER VAPOR PRESSURE.

$$\text{Correction factor} = \frac{(14.4 - P_t)\,(t - 100)}{460 + t} - (P_{100} - P_t)$$

where t = the air chamber temperatuıe at beginning of test, deg. Fahr.
P_t = the vapor pressure of water, lb. per sq. in., at t° F.
P_{100} = the vapor pressure of water, lb. per sq. in., at 100° F.
14.4 = the atmospheric pressure in lb. per sq. in.

AIR BOMB TEMPERATURE, DEG. FAHR.	CORRECTION, LB. PER SQ. IN.	AIR BOMB TEMPERATURE, DEG. FAHR.	CORRECTION, LB. PER SQ. IN.	AIR BOMB TEMPERATURE, DEG. FAHR.	CORRECTION, LB. PER SQ. IN.
32	−2.9	60	−1.8	86	−0.7
34	−2.8	62	−1.8	88	−0.6
36	−2.7	64	−1.7	90	−0.5
38	−2.7	66	−1.6	92	−0.4
40	−2.6	68	−1.5	94	−0.3
42	−2.5	70	−1.4	96	−0.2
44	−2.5	72	−1.3	98	−0.1
46	−2.4	74	−1.3	100	0.0
48	−2.3	76	−1.2	102	+0.1
50	−2.2	78	−1.1	104	+0.2
52	−2.1	80	−1.0	106	+0.3
54	−2.0	82	−0,9	108	+0.5
56	−2.0	84	0 8	110	+0.6
58	−1.9				

Calculating Results.

8. To calculate the vapor pressure of the gasoline, the final gage pressure recorded must be corrected for the change in the pressure of the air in the chamber due to its increase in temperature and for the increased pressure of water vapor at the higher temperature. These corrections have been combined and are given in Table II.

To calculate the vapor pressure of the sample, the figure given opposite the air chamber temperature in Table II is subtracted from or added to the observed pressure reading. Thus if the air chamber temperature is 80° F. and the final gage reading is 24.5 lb. per sq. in., the vapor pressure of the sample is $24.5 - 1.0 = 23.5$ lb. per sq. in. absolute.

TENTATIVE SPECIFICATIONS
FOR
CALCIUM CHLORIDE FOR DUST PREVENTION.[1]

A.S.T.M. Designation: D 98-30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1921; REVISED, 1922, 1930.

Scope.

1. These specifications cover calcium chloride to be applied to the surface of highways as a dust preventive.

PROPERTIES AND TESTS

Physical Properties.

2. The calcium chloride shall be in the form of loose dry lumps or flakes, and when tested by means of laboratory screens and sieves shall conform to the following requirements:

Passing 3/8-in. screen	100 per cent
Retained on 1/4-in. screen	not more than 20 "
Passing No. 20 sieve	not more than 10 "

Chemical Composition.

3. The calcium chloride shall conform to the following requirements as to chemical composition:

$CaCl_2$ (anhydrous)	not less than 73 per cent
$MgCl_2$	not more than 0.5 "
NaCl	not more than 2.0 "
Other impurities	not more than 1.0 "

PACKAGES

Packages.

4. The calcium chloride shall be delivered in moisture-proof bags or sacks containing approximately 100 lb. each, or in air-tight steel drums weighing not more than 450 lb. each. The name of the manufacturer, the lot number, the approximate net weight, and the percentages of calcium chloride guaranteed by the manufacturer shall be plainly marked on each container.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 801 Second Ave., New York City.

INSPECTION AND REJECTION

Inspection. 5. Every facility shall be provided the purchaser should he elect to have his own representative sample the material at the plant. If the purchaser decides to sample the material after delivery in the field it is understood that a 3-per-cent variation in content of $CaCl_2$ from the chemical composition stated in Section 3 shall be permissible.

Rejection. 6. Calcium chloride shall be rejected if it fails to pass any of the requirements of these specifications and if it has become caked or sticky in the containers before opening.

TENTATIVE DEFINITION
OF
THE TERM COKE[1]

A.S.T.M. Designation: D 121 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1921; Revised, 1924, 1926, 1930.

Coke.—The infusible, cellular, coherent solid material obtained from coal as the residue from its destructive distillation.

Note 1.—Such material obtained from the destructive distillation of petroleum or petroleum residues is known as "petroleum coke."

Note 2.—Such material obtained from the destructive distillation of coal-tar pitch is known as "pitch coke."

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[1] Criticisms of this Tentative Definition are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

This tentative definition, when adopted as standard, will be added to the present Standard Definitions of Terms Relating to Coal and Coke (A.S.T.M. Designation: D 121 – 30), see 1930 Book of A.S.T.M. Standards, Part II, p. 752.

TENTATIVE SPECIFICATIONS
FOR
TIMBER PILES[1]

A.S.T.M. Designation: D 25 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED AS TENTATIVE, 1915: ADOPTED, 1920: REISSUED AS TENTATIVE IN AMENDED FORM, 1930.

Scope. 1. These specifications cover untreated round timber suitable for timber piles but contain requirements for timber suitable for treatment by standard preservative processes. Where sawed timber is used as piling, such as heavy sheet piles, appropriate specifications should be selected from the Standard Specifications for Structural Wood Joist and Planks, Beams and Stringers and Posts and Timbers (A.S.T.M. Designation: D 245) of the American Society for Testing Materials.[2]

Kinds of Wood. 2. (*a*) The purchaser shall specify the kind or kinds of wood he desires to use, and shall designate the kinds he desires for preservative treatment. The most commonly used species are cedars, cypress, Douglas fir, oaks, pines and spruces.

(*b*) Piles of different kinds of wood shall be delivered in separate lots.

PHYSICAL PROPERTIES

A. First-Class Piles:

General Quality. 3. Except as hereinafter provided, all piles shall be free from any defects which may impair their strength or durability as piling, such as decay, red heart, splits in piles to be treated, or splits longer than the measured butt diameter of piles not to be treated, twist of grain exceeding one-half of the circumference in any 20 ft. of length, unsound knots, numerous knots or holes, or shake more than one-third of the diameter of the pile.

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, U. S. Forest Products Laboratory, Madison, Wis.

These specifications are in effect a revision of the former Standard Specifications for Southern Yellow-Pine Piles and Poles to be Creosoted (A.S.T.M. Designation: D 25 - 20), which specifications were accordingly discontinued in 1930.

The requirements of these specifications are in accordance with the Specifications for Timber Piles adopted by the Committee on Wooden Bridges and Trestles of the American Railway Engineering Assn., published in the A.R.E.A. Manual, p. 469, 1929.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 754.

4. *Knots.*—Sound knots will be permitted, provided they are not in clusters. The maximum diameter of a sound knot shall not be greater than one-third of the least diameter of the section where it occurs, and shall not exceed 4 in. A sound knot shall be one which at a depth not greater than its diameter shows wood as hard as that surrounding the knot.

5. (*a*) All piles shall be cut from sound, live trees, except that fire-killed, blight-killed, or wind-felled timber may be used if not attacked by decay or insects.

(*b*) *Tip.*—The tip shall be sound.

(*c*) *Butt End.*—The butt end shall be sound in all except cedar piles, which may have a pipe or stump rot hole not more than 1½ in. in diameter.

Close Grain.

6. If close grain is specified for softwood piles, they shall show on the butt end not less than six annual rings per inch, measured radially over the outer 3 in. of the cross-section. Douglas fir and southern pine averaging from five to six annual rings per inch shall be accepted as the equivalent of close grain if they have one-third or more summerwood.

Preservative Treatment.

7. (*a*) Piles for use without preservative treatment shall have as little sapwood as possible.

(*b*) Piles for use with preservative treatment shall have no sapwood restrictions, but preferably shall contain as much sapwood as possible. In southern pine the sapwood thickness shall not be less than 1½ in. and in Douglas fir not less than 1 in. on the butt end.

Peeling.

(*c*) Piles shall be peeled of bark, including the inner skin, soon after cutting so that the piles are smooth and clean. Care shall be taken to remove as little sapwood as possible while peeling the bark. The sapwood shall not be injured by unnecessary axe cuts. These piles shall be designated as sap piles.

B. Second-Class Piles:

General Quality.

8. Piles for foundations that will always be completely submerged and piles for coffer-dams, falsework and sundry temporary work may be of sound, live timber that will stand driving, and need not be peeled. They shall be free from bad knots, decayed timber, shakes and other imperfections which will seriously affect their strength.

DIMENSIONS AND PERMISSIBLE VARIATIONS

9. The diameter of a pile in cases where the tree is not exactly round shall be determined by measuring the circumference and dividing the number of inches by 3.14.

Dimensions of First-Class Piles.

10. The diameters of first-class piles shall conform to the following requirements, subject to a permissible variation of minus ½ in. in any given diameter in not more than 25 per cent of the pieces of that diameter:

SOUTHERN PINE AND DOUGLAS FIR PILES

Length, ft.	Diameter 3 ft. from Butt, in. Minimum	Diameter 3 ft. from Butt, in. Maximum	Diameter of Tip, in. Minimum
Under 40	14	18	10
40 to 50	14	18	9
50 to 70	14	18	8
70 to 90	14	18	7
Over 90	14	20	6

RED OAK, WILLOW OAK, BLACK OAK, WHITE OAK, PIN OAK, POST OR BURR OAK, OR CYPRESS PILES

Length, ft.	Diameter 6 ft. from Butt, in. Minimum	Diameter 6 ft. from Butt, in. Maximum	Diameter of Tip, in. Minimum
Under 30	12	18	10
30 to 40	12	18	9
Over 40	12	18	8

WESTERN RED CEDAR PILES

Length, ft.	Diameter 6 ft. from Butt, in. Minimum	Diameter 6 ft. from Butt, in. Maximum, Widest Part	Diameter of Tip, in. Minimum, Any Point
Up to 30 inclusive	14	22	10
30 to 40	14	22	9
Over 40	14	22	8

Dimensions of Second-Class Piles.

11. The diameters of second-class piles shall conform to the following requirements, subject to a permissible variation of minus ½ in. in any given diameter in not more than 25 per cent of the pieces of that diameter:

Length, ft.	Diameter 3 ft. from Butt, in. Minimum	Diameter 3 ft. from Butt, in. Maximum	Diameter of Tip, in. Minimum
Up to 40 inclusive	12	18	8
Over 40	12	18	6

Length.

12. All piles shall be furnished on order cut to any of the following lengths: 16 to 40 ft. in multiples of 2 ft., and over 40 ft. in multiples of 5 ft. A variation of 6 in. in length shall be allowable, but the average length in any shipment shall be equal to, or greater than, the specified lengths. The length of each pile shall be legibly marked on the butt end with white or black paint.

Straightness.

13. Piles shall be free from short or reversed bends, and free from crooks greater than one-half of the diameter of the pile at the middle of the bend. A line drawn from the center of the butt end to the center of the tip shall lie within the body of the pile.

WORKMANSHIP AND FINISH

14. Piles shall have a uniform taper from the point of butt measurement to the tip. **Taper.**

15. All knots and limbs shall be trimmed or smoothly cut flush with the surface of the pile. Ends shall be cut square with the axis of the pile. **Surface Finish.**

16. No piece shall be considered as thoroughly peeled unless all of the rough bark and at least 80 per cent of the inner bark shall have been removed. In no case shall any piece of inner bark be over $\frac{3}{4}$ in. in width or over 8 in. in length, and there shall be 1 in. of clean wood surface between any two strips. **Peeled Piles.**

TENTATIVE METHOD OF TEST
FOR
THE DETERMINATION OF THE SPECIFIC GRAVITY, 38°/15.5° C., OF CREOSOTE FRACTIONS[1]

A.S.T.M. Designation: D 38 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. This method is a convenient and accurate means of determining the specific gravity of the relatively small amounts of distillation fractions of creosote. It is also suitable for creosote oil and creosote coal-tar solution where only small amounts are available.

Apparatus. 2. The apparatus shall consist of the following:

(*a*) *Pycnometers.*—Pycnometers of 10 and 25-ml. capacities with ground-glass stoppers having the usual capillary openings.

(*b*) *Water Bath.*—A water bath consisting of a vessel filled with sufficient water to permit of maintaining at a temperature of 38° C. ± 1° C.

(*c*) *Thermometer.*—A thermometer graduated in centigrade degrees, the range being −2 to +80° C. and conforming to the requirements of the A.S.T.M. low softening-point thermometer specified in Section 4 of the Standard Method of Float Test for Bituminous Materials (A.S.T.M. Designation: D 139) of the American Society for Testing Materials.[2]

Calibration of Pycnometer. 3. Before making a determination the pycnometer with stopper shall first be calibrated as follows: Weigh the empty, clean, dry pycnometer with stopper upon an analytical balance; fill with freshly-boiled distilled water, place in the water bath and bring temperature to 38.0° C. ± 0.1° C., insert stopper, wipe dry and weigh.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, U. S. Forest Products Laboratory, Madison, Wis.

This tentative method, when adopted, will be added to the present Standard Methods of Sampling and Analysis of Creosote Oil (A.S.T.M. Designation: D 38 – 30), 1930 Book of A.S.T.M. Standards, Part II, p. 874.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 660.

Procedure.

4. The specific gravity shall be determined as follows:

Heat the fraction until completely liquid, and pour into the empty, dry pycnometer until full, avoiding the formation of air bubbles. Place the filled pycnometer in the water bath maintained at a temperature of 38.0° C. ± 0.1° C.; after at least 30 minutes immersion in the bath, insert the stopper firmly, wipe dry and weigh. Use the 10-ml. bottle for the 315 to 355° C. fraction. The 25-ml. bottle may be used for the larger fraction.

Calculation.

5. The expression "38°/15.5° C." means specific gravity of the fraction determined at 38° C. compared with water at 15.5° C. This cannot be obtained directly. The specific gravity of the fraction is first determined at 38° C., compared with water at 38° C. and this determination represents the relation of the weight of a volume of oil at 38° C. to the weight of an equal volume of water at the same temperature. The relation to an equal volume of water at 15.5° C. is obtained by multiplying the former figure by 0.99393, the density of water at 38° C. compared to water at 15.5° C., $\frac{(0.99299).}{(0.99905)}$ From the foregoing, it will be readily seen that it is incorrect to calculate the specific gravity at 38°/15.5° C. by dividing the weight of the oil taken at 38° C. by the weight of the water taken at 15.5° C.

Example.—Where the weight of the empty pycnometer is 23.7531 g.; the weight of the pycnometer filled with water at 38° C. is 78.1128 g.; the weight of the pycnometer filled with oil at 38° C. is 80.2755 g.; the specific gravity at 38°/15.5° C. is calculated as follows:

$$\text{Specific gravity corrected to } 38°/15.5° \text{ C.} = \frac{80.2755 - 23.7531}{78.1128 - 23.7531} \times 0.99393 = 1.0335$$

TENTATIVE DEFINITIONS
OF
TERMS RELATING TO TIMBER PRESERVATIVES[1]

A.S.T.M. Designation: D 324 – 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1930.

Creosote (*Creosote Oil*).—As used in wood preserving, a distillate of coal tar produced by high-temperature carbonization of bituminous coal; it consists principally of liquid and solid aromatic hydrocarbons, and contains appreciable quantities of tar acids and tar bases; it is heavier than water; and has a continuous boiling range of at least 125° C. beginning at about 200° C.

Creosote Coal-Tar Solution.—Solution of coal tar in creosote in various proportions. Usually contains 20 to 40 per cent of coal tar.

Creosote Distillate.—Same as for *Creosote* (*Creosote Oil*).

Coal Tar.—See *Tar, Coal.*

Tar, Coal.—The nonaqueous portion of the liquid distillate obtained during the carbonization of bituminous coal.

Tar, Coal-Gas (*Gas-House Tar*).—Coal tar produced during the manufacture of illuminating gas in gas retorts.

Tar, Coke-Oven.—Coal tar produced during the manufacture of coke in by-product coke ovens.

Tar, Water-Gas.—Tar produced in the manufacture of carbureted water gas by the decomposition of petroleum oil by heat in the presence of blue gas.

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[1] **Criticisms of these Tentative Definitions are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, U. S. Forest Products Laboratory, Madison, Wis.**

TENTATIVE METHODS OF TESTING ASPHALT ROLL-ROOFING SURFACED WITH FINE TALC, GRANULAR TALC, OR MINERAL GRANULES, LIKEWISE ASPHALT SHINGLES SURFACED WITH MINERAL GRANULES[1]

A.S.T.M. Designation: D 228 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED AS TENTATIVE, 1925; ADOPTED, 1927; REISSUED AS TENTATIVE, 1930.

Scope. 1. These methods cover the examination of roofings and shingles composed of roofing felt, saturated and coated on both sides with asphalt, and surfaced on the top with either powdered or granulated mineral matter, and on the under side with powdered mineral matter.

SAMPLING

Sampling. 2. From each shipment or portion thereof representing a product of the same kind, class and weight, a number of rolls or bundles shall be selected at random, equivalent to one-half the cube root of the total number of rolls or bundles included in the lot, except that in lots of 1000 or less, five rolls or bundles shall be taken. If the cube root, as calculated, proves to be a fractional number, it shall be expressed as the nearest higher whole number. For convenience, the following table is given, showing the number of samples to be selected from shipments of various sizes:

PACKAGES IN SHIPMENT	NUMBER OF PACKAGES SELECTED	PACKAGES IN SHIPMENT	NUMBER OF PACKAGES SELECTED
Up to 1000	5	5 833 to 8 000	10
1001 to 1728	6	8 001 to 10 648	11
1729 to 2744	7	10 649 to 13 824	12
2745 to 4096	8	13 825 to 17 576	13
4097 to 5832	9	17 577 to 21 952	14

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-8 on Bituminous Waterproofing and Roofing Materials, 801 Second Ave., New York City.

DETERMINATION OF SIZE AND WEIGHT

(*A*) *Smooth and Mineral-surfaced Roll-Roofing.*

Stripping. 3. Each roll selected shall be stripped. The wrappers, packing material, nails and cement taken from each roll shall be weighed together to the nearest $\frac{1}{4}$ lb. and the maximum weight thereof per roll shall be recorded. The quantity and character of nails and cement shall be recorded.

Workmanship and Finish. 4. Each roll shall be unwound, discarding any detached surfacing that may fall off in so doing, and the workmanship and finish of the roofing observed.

Area. 5. The length and width of each roll shall be measured to the nearest $\frac{1}{4}$ in., and the square feet of material contained in each roll calculated. From this, the average area of the rolls examined shall be calculated.

Minimum Weight. 6. The rolls shall be rewound, fastened with pieces of light string and then each roll shall be weighed to the nearest $\frac{1}{4}$ lb. The weight of roofing per 108 sq. ft. contained in each roll shall be calculated and the minimum weight per 108 sq. ft. recorded. This shall be regarded as the minimum weight per 108 sq. ft. of the entire shipment.

Average Weight. 7. The average weight per 108 sq. ft. for the rolls examined shall be calculated. This shall be regarded as the average weight per 108 sq. ft. of the entire shipment.

Weight per 108 sq. ft. 8. From the rolls examined, the one whose weight per 108 sq. ft. is nearest the average weight of the lot shall be selected. The first convolution or two shall be unrolled, and with a knife and straight edge, the sheet shall be cut across at right angles to the edges. A section measuring exactly 30 in. in the direction of the roll's length shall then be removed. The width of this section shall be measured to the nearest $\frac{1}{32}$ in. and weighed with an accuracy of $\frac{1}{4}$ oz. The weight in pounds per 108 sq. ft. shall then be calculated from the following formula:

$$\text{Pounds per 108 sq. ft.} = \frac{\text{Weight of 30-in. section in ounces}}{\text{Width of 30-in. section in inches}} \times 32.4$$

This must check within 1 per cent of the average weight per 108 sq. ft. of the shipment (Section 7). If this sample fails to do this, then additional samples shall be cut from the same roll, until one is obtained which does, which sample shall be kept for further examination.

NOTE.—As a referee method, or in case any dispute arises regarding the properties as may be ascertained from the particular sample selected, a 30-in. sample shall be taken and examined separately from each roll sampled in Section 2.

(*B*) *Mineral-surfaced Shingles*

9. Each bundle selected shall be stripped. The packing material shall be weighed to the nearest $\frac{1}{4}$ lb., recording the weight separately for each bundle. The maximum weight of packing material per "square" shall be recorded. **Stripping.**

10. The shingles in each bundle, a, shall be counted, discarding any detached surfacing that may fall off in so doing. The workmanship and finish of the shingles shall be observed. **Workmanship and Finish.**

11. The shingles contained in each bundle shall be weighed to the nearest $\frac{1}{4}$ lb., b. The dimensions of the shingles shall be accurately measured and the net area of material in each shingle calculated in square feet, c. **Area.**

12. The area in square feet of material contained in each bundle, $a \times c$, shall be calculated. The weight of roofing material per 108 sq. ft. contained in each bundle $\left(\frac{b}{a \times c} \times 108\right)$ shall be calculated, and the minimum weight per 108 sq. ft. recorded. This shall be regarded as the minimum weight per 108 sq. ft. of the entire shipment. **Minimum Weight.**

13. The average weight, d, per 108 sq. ft. for the bundles examined shall be calculated. This shall be regarded as the average weight per 108 sq. ft. of the entire shipment. Also, the average weight per shingle, $\left(\frac{c \times d}{108}\right)$ shall be calculated. **Average Weight.**

14. From the bundles selected, a definite number of representative shingles, whose weight shall fall within 1 per cent of the average weight ascertained in Section 13 shall be taken for further consideration. The number of shingles so selected shall represent as closely as possible 6 sq. ft. of material, and shall be selected as far as possible from different bundles. **Selective Sampling.**

NOTE.—As a referee method, or in case any dispute arises regarding the properties as may be ascertained from the particular sample selected, then a similar sample shall be taken and examined separately from each bundle of shingles sampled in Section 2.

DETERMINATION OF PLIABILITY OF SMOOTH ROLL-ROOFING AND MINERAL-SURFACED ROLL-ROOFING

15. With a photographic trimmer five strips shall be cut from the sample of roofing, each 1 in. in width and 6 in. in length, in the direction of the fiber grain, and immersed in water at 77° F. (25° C.) for 10 to 15 minutes. These strips shall be removed from the water and **Pliability.**

immediately bent through 180 deg. at uniform speed, in exactly 2 seconds, over a mandrel of the following size:

Smooth Roll-Roofing—At least 3 of the 5 strips shall not crack over a mandrel 10 mm. in diameter.

Mineral-surfaced Roll-Roofing—At least 3 of the 5 strips shall not crack on a mandrel 25 mm. in diameter.

DETERMINATION OF BEHAVIOR ON HEATING

Behavior on Heating.

16. Two strips shall be cut from the sample of roofing or shingles, each approximately 8 by 8 in. They shall be weighed and suspended vertically in the center of an air-oven maintained at 176° F. (80° C.) ±5°F. (3° C.) with a thin wire fastened through holes punctured near one edge. The thermometer shall be inserted in the oven to such a depth that its bulb will be in line with the center of the specimens. The strips shall be maintained at the prescribed temperature for exactly two hours, then cooled, removed carefully and each specimen weighed. The average loss shall be calculated as a percentage. Any change in appearance of the specimen shall be recorded, such as flowing, sagging, blistering or absorption of the surface coatings; also sliding of granular surfacing.

DETERMINATION OF SATURANT IN MOISTURE-FREE FELT

Percentage of Saturation.

17. Two strips shall be cut from the sample of roofing or shingles, each approximately 2 in. in width and 8 in. in length. They shall be warmed in an oven at a temperature of approximately 176° F. (80° C.). Then with a knife, the front and back coatings shall be peeled off, care being taken to remove as little as possible of the saturated felt, and to assure that all of the coatings and surfacing are stripped from the felt. The saturated felt so obtained shall be weighed. It shall be extracted with benzol, chloroform, carbon tetrachloride or carbon disulfide, in a suitable extractor and the extraction continued until the drippings have become colorless. The desaturated felt shall be removed from the extractor, placed in a tared vessel, heated in a ventilated oven at 225° F. (107° C.) for 30 minutes, cooled in a desiccator, and the felt finally weighed as rapidly as possible. The heating shall be repeated until the weight of the felt remains constant as determined by two consecutive weighings taken not less than 10 minutes apart, which shall show a further loss of not more than 0.1 per cent. From the weight so obtained and the original weight, the percentage of saturation carried by the moisture-free felt shall be computed.

DETERMINATION OF WEIGHT OF MOISTURE-FREE FELT

18. Two strips shall be cut from the sample of roofing or shingles, each approximately 2 in. in width and 8 in. in length. Each of these shall be accurately weighed in grams and the length and width measured to within 1 mm. or $\frac{1}{32}$ in. It shall be extracted with carbon disulfide,[1] in a suitable extractor and the extraction continued until the drippings have become colorless. The desaturated felt shall be removed from the extractor, being careful not to lose any adhering mineral matter, placed in a tared vessel, heated in a ventilated oven at 225° F. (107° C.) for 30 minutes, cooled in a desiccator, any adhering surfacing material brushed off and retained and the felt finally weighed as rapidly as possible. The heating shall be repeated until the weight of the felt remains constant as determined by two consecutive weighings taken not less than 10 minutes apart, which shall show a further loss of not more than 0.1 per cent. The carbon disulfide extract and accompanying mineral matter shall be retained for further examination. From the weights so obtained and the respective areas of the strips of desaturated felt, the weight of moisture-free felt shall be computed in pounds per 108 sq. ft., from the following formulas and the results averaged:

Weight of Moisture-Free Felt.

$$\text{Pounds per 108 sq. ft.} = \frac{\text{Weight of moisture-free felt in grams}}{\text{Area of specimen in square centimeters}} \times 221.2$$

or

$$\text{Pounds per 108 sq. ft.} = \frac{\text{Weight of moisture-free felt in grams}}{\text{Area of specimen in square inches}} \times 34.3$$

DETERMINATION OF ASH IN MOISTURE-FREE FELT

19. The strips of desaturated felt obtained as described in Section 18 shall be cut into squares about 2 cm. on each side and thoroughly mixed. Pieces amounting to about 10 g. shall be selected at random and dried at 225° F. (107° C.) for 30 minutes. They shall be cooled in a desiccator, accurately weighed and then incinerated in a weighed crucible either over an open flame or in a muffle until all the carbon is consumed. A few drops of ammonium carbonate solution shall then be added, the sample ignited gently and weighed. The percentage of ash shall be calculated on the basis of the moisture-free felt.

Ash.

DETERMINATION OF MINERAL SURFACING AND MINERAL MATTER IN COATINGS

20. (*a*) The slate and other mineral matter recovered from the extraction process described in Section 18 shall be combined with the mineral matter removed from the surface of the desaturated felt and

Mineral Matter.

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[1] **In this test, chloroform may be used as an equivalent solvent.**

that resulting from the evaporation and ignition of the carbon disulfide extract. The mineral matter shall be dried in air free from the odor of carbon disulfide, then heated in an oven for 30 minutes at 225° F. (107° C.), and finally cooled in a desiccator and weighed. From the combined weight of the specimens taken in Section 18, the total "mineral surfacing and mineral matter in the coatings" shall be calculated in pounds per 108 sq. ft.

(*b*) For asphalt roll-roofing surfaced with granular talc, the mineral matter recovered as described in Paragraph (*a*) shall be washed through a No. 65 copper-wire sieve with three washings of water of 100 cc. each. The total aqueous suspension of mineral matter which passes through the sieve shall then be filtered through a weighed Gooch crucible. It shall then be dried at 225° F. (107° C.) and reweighed. The difference in weight represents the mineral matter passing a No. 65 sieve which shall be converted into pounds per 108 sq. ft.

TENTATIVE METHOD OF COMPRESSION TESTING OF NATURAL BUILDING STONE[1]

A.S.T.M. Designation: D 326 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.[2]

Scope. 1. This method of test is intended for the determination of the compressive strength of natural building stones used for exterior or interior construction or decorative purposes.

APPARATUS

Testing Machine. 2. Any form of standard testing machine may be used for the compression test together with a spherical bearing block large enough to entirely cover the specimen, but not greater in diameter than three times the width of the loaded face of the specimen.

TEST SPECIMENS

Test Specimens. 3. (*a*) Samples shall be representative of the material and shall consist of sections cut from apparently sound material, preferably quarry blocks or slabs. The direction of the bedding planes or rift shall be plainly marked on the sample. The sample shall be of sufficient size to allow the preparation of not less than three specimens having the bedding planes or rift running in the proper direction for the kind of test specified, that is, either parallel or perpendicular to the face of the specimen to which pressure is to be applied in the test. (See Fig. 1.)

(*b*) Specimens shall be either cubical or cylindrical in form. If cylindrical the height of the cylinders shall be not less than the diameter nor exceed the diameter by more than 25 per cent. For all standard tests either a $2\frac{1}{2}$-in. cube, or a $2\frac{1}{2}$-in. cylinder having a height of $2\frac{1}{2}$ in. shall be used.

(*c*) The specimens shall be cut from the original samples either with saws or core drills, no hand cutting with chisels or other tools shall be permitted. The load-bearing surfaces shall be finished to as nearly true and parallel planes as possible, grinding wheels or the use of abrasive powders and rubbing plates affording convenient means of obtaining satisfactory surfaces. If cubical specimens are used the non-load bearing sides shall also be finished to approximate planes.

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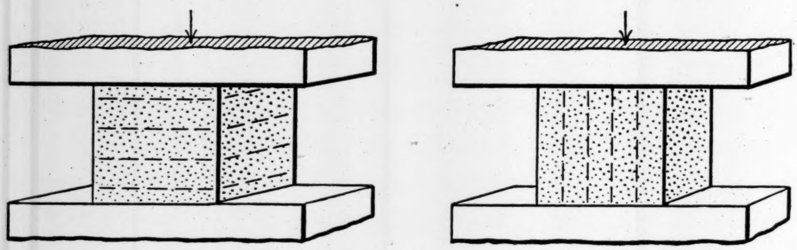
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. H. S. Brightly Secretary of Committee D-18 on Natural Building Stones, Box 54, Bloomington, Ind.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 12, 1930.

Marking Specimens. 4. The load-bearing surfaces and the direction of the bedding planes or rift shall be carefully marked on each specimen after finishing.

Measurements. 5. The dimensions of the specimen shall be measured to the nearest 0.01 in. The areas of the load-bearing surfaces shall be averaged for the calculation of the compressive strength. The height of the specimen shall be furnished in the report as information only.


Perpendicular to Bedding

Parallel to Bedding

Dashed lines indicate direction of bedding.
Arrows indicate direction of loading.

FIG. 1.—Methods of Applying Load with Reference to Bedding.

PROCEDURE

Conditioning. 6. (*a*) *Dry Condition.*—Specimens to be tested in the dry condition shall be dried in an oven at from 110 to 120° C. for 24 hours immediately previous to the test.

(*b*) *Wet Condition.*—Specimens to be tested in the wet condition shall be completely immersed in water at room temperature for at least two weeks and shall be kept in water until immediately preceding the test.

Procedure. 7. The specimens shall be centered in the testing machine with the spherical bearing block on the top in vertical testing machines. The center of the spherical surface of the bearing block shall be in the face in contact with the top bearing surface of the specimen. The spherical bearing shall be kept well lubricated to insure accurate adjustment which should be made by hand under a small initial load. The speed of the moving head of the testing machine during the application of the load shall be not more than 0.05 in. per minute. During the test the beam of the testing machine shall be kept constantly in a floating position.

Calculation.

8. The compressive strength in pounds per square inch shall be calculated from the formula:

$$C = \frac{W}{A}$$

where C = the compressive strength, lb. per sq. in.,

W = the total maximum load in pounds indicated by the testing machine, and

A = average area of the two bearing surfaces of the specimen.

Reporting Results.

9. (*a*) Each individual test shall be reported and for the compressive strength of the material the average of all tests shall be used except where an individual result varies from the average of its group more than 25 per cent of that average, in which case that individual result shall be reported only as information.

(*b*) When the load has been applied on a line perpendicular to the bedding or rift planes the result shall be reported as "compressive strength in pounds per square inch perpendicular to the bedding or rift."

(*c*) When the load has been applied on a line parallel to the bedding or rift planes the result shall be reported as "compressive strength in pounds per square inch parallel to the bedding or rift."

Report.

10. The report shall include the following:

(*a*) The individual and averaged compressive strengths in pounds per square inch for each group of specimens;

(*b*) The types and approximate sizes of specimens used;

(*c*) The condition of the specimen when tested, whether wet or dry;

(*d*) The direction of the application of the load relative to the bedding planes or rift of the specimens;

(*e*) A definite statement as to manner in which specimens were prepared and finished.

TENTATIVE METHOD OF FLEXURE TESTING OF NATURAL BUILDING STONE[1]

(DETERMINATION OF MODULUS OF RUPTURE)

A.S.T.M. Designation: D 327 – 30 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.[2]

Scope. 1. This method of test is intended for the determination of the modulus of rupture of natural building stones used for exterior or interior construction or decorative purposes.

APPARATUS

Testing Machine. 2. The testing machine shall be sensitive to 0.5 lb. when loaded to 500 lb.

Knife Edges. 3. For the support of the test specimen a set of knife edges similar to those shown in Fig. 1 shall be provided. The load shall be applied through a third knife edge of the same type.

TEST SPECIMENS

Test Specimens. 4. The sample supplied shall be of sufficient size to provide all of the specimens required for the test. The test specimens shall be sawed from the sample and shall be finished as closely as practicable to 12 by 4 by 1 in. in size either by the use of grinding wheels or by hand rubbing with abrasive powders on steel plates. The 12 by 4-in. faces shall be made as nearly plane and parallel as practicable. No chiseling or other hand cutting shall be permitted.

Types of Specimens. 5. Three or more specimens shall be prepared for each required combination of load application and bedding or rift plane direction, such as are shown in Fig. 2, and noted below:

(*a*) Load applied perpendicular to bedding or rift planes;

(*b*) Load applied parallel to bedding or rift planes;

(*c*) Load applied perpendicular to bedding or rift planes with the bedding or rift planes vertical.

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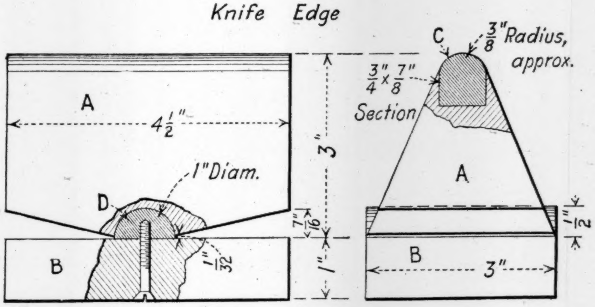
[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. H. S. Brightly, Secretary of Committee D-18 on Natural Building Stones, Box 54, Bloomington, Ind.

[2] Accepted for publication as tentative by Committee E-10 on Standards, August 12, 1930.

PROCEDURE

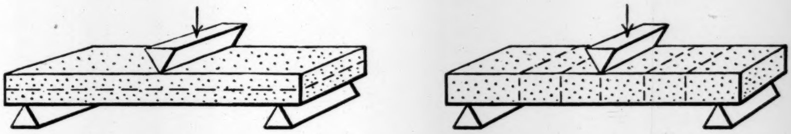
6. The thickness and width of the specimen at the mid-section shall be measured to the nearest 0.01 in.

7. Before testing, the specimens shall be dried in an oven at a temperature of 110 to 120° C. for 24 hours.


Knife Edge
A
$4\frac{1}{2}''$
1" Diam.
D
3"
$\frac{7}{16}''$
1"
$\frac{1}{32}''$
B
C
$\frac{3}{8}''$ Radius, approx.
$\frac{3}{4}'' \times \frac{7}{8}''$ Section
A
$\frac{1}{2}''$
B
3"

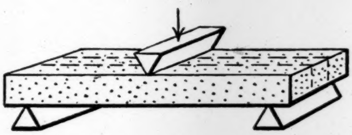
A, B = Cast Iron Wedges.
C, D = Cold-Rolled Steel.

FIG. 1.—Self-Adjusting Knife-Edge Bearing and Load-Application Device.



Perpendicular to Bedding

Parallel to Bedding



Perpendicular on Edge

Dashed lines indicate direction of bedding.
Arrows indicate direction of loading.

FIG. 2.—Methods of Applying Load with Reference to Bedding.

8. The test specimen shall be supported on the knife edges on 10-in. centers and the load applied at the center of the specimen through the third knife edge (see Fig. 2). The load shall be applied at the rate of 100 lb. per minute. The breaking load shall be recorded to the nearest 5 lb.

Calculation. 9. The modulus of rupture shall be calculated from the formula:

$$R = \frac{3wl}{2bd^2}$$

where R = modulus of rupture;
w = breaking load in pounds;
l = length of span in inches;
b = width of specimen in inches; and
d = thickness of specimen in inches.

Reporting Results. 10. The average value of the modulus obtained from a group of not less than two specimens shall be reported as the modulus of rupture for the condition of loading and direction of bedding or rift used. In case any specimen shows a value 25 per cent lower than the average of its group it shall be examined for defects and if the low value appears to be due to imperfections the average of the other specimens in the group shall be reported as the modulus of rupture of the group. All determinations shall be reported as information.

TENTATIVE METHODS OF TEST FOR ABSORPTION AND APPARENT SPECIFIC GRAVITY OF NATURAL BUILDING STONE[1]

A.S.T.M. Designation: D 328 – 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.[2]

Scope. 1. These methods of test are intended for the determination of the absorption by weight or by volume, and for the apparent specific gravity of natural building stones used for exterior or interior construction. The calculation of the dry weight of the stone in pounds per cubic foot may also be made from the results of the apparent specific gravity test.

A. Absorption Test

Test Specimens. 2. Samples shall be supplied of sufficient size to provide not less than three test specimens of some regular form such as a cube, prism, or cylinder whose greatest dimension shall be not more than 3 in. and whose least dimension shall be not less than 2 in. All surfaces of specimens shall be smooth finished. No chisels or other hand tools shall be used in finishing specimens.

Conditioning. 3. The specimens shall be dried in an oven at a temperature between 110 and 120° C. for a period of at least 24 hours.

Weighing. 4. (*a*) After drying, the specimens may be cooled in the room for 30 minutes and then weighed. In cases where the specimens cannot be weighed immediatly after cooling, they shall be placed in a desiccator. The weight shall be determined to the nearest 0.05 g.

(*b*) After the initial weighing, the specimens shall be wholly immersed in distilled water at approximately 20° C. for two weeks. At the end of this period the specimens shall be removed, all faces and edges thoroughly wiped off with a dry cloth and the specimen immediately weighed to the nearest 0.05 g.

Calculation. 5. The percentage of absorption shall be calculated from the formula:

$$\text{Percentage of absorption} = \frac{100(B - A)}{A}$$

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[1] **Criticisms of these Tentative Methods are solicited and should be directed to Mr. H. S. Brightly, Secretary of Committee D-18 on Natural Building Stones, Box 54, Bloomington, Ind.**

[2] **Accepted for publication as tentative by Committee E-10 on Standards, August 12, 1930.**

where A = the dry weight of the specimen; and
B = the weight of the specimen after immersion.

Reporting Results. 6. (*a*) In general, the average of all the tests shall be reported as the absorption of the stone. Individual determinations which differ by more than 25 per cent from the average of all the determinations may be disregarded when there is evidence that such results are of uncertain value. The absorption shall then be reported as the average of the remaining determinations, but all determinations shall be reported as information.

(*b*) The absorption value obtained from this test is the percentage absorption by weight. To convert the result to percentage absorption by volume multiply by the value of the apparent specific gravity as determined with the same specimens in accordance with Method B. Apparent Specific Gravity, described in Sections 8 and 9.

Report. 7. The report of the absorption test shall state whether the absorption has been determined according to weight or volume and, if the percentage of volume absorption is reported, there shall also be reported the percentage absorption by weight and the apparent specific gravity.

B. *Apparent Specific Gravity*

Weighing. 8. To obtain the apparent specific gravity the weight of the specimen suspended in water shall be determined immediately after the weighing of the specimen described in Section 4 (*b*) (see Note).

NOTE.—When weighing the specimen suspended in water, various methods of suspending the specimen from the balance beam are in use. Fine silk thread or a cradle of light wire whose weight has been carefully determined may be convenient. The cradle should be of such construction that there will be no possibility of air bubbles forming in it. The water container should be of glass and may be supported on a platform which straddles the balance pan, this method allowing the weighings to be made without detaching the pan.

Calculation. 9. (*a*) Having found the weight of the specimen when suspended in water the apparent specific gravity shall be calculated from the formula:

$$\text{Apparent specific gravity} = \frac{A}{B - C}$$

where A = the dry weight of the specimen;
B = the wet weight of the specimen after immersion; and
C = the weight of the specimen suspended in water.

(*b*) The apparent specific gravity shall be calculated for those specimens whose absorption values are to be averaged as described in Section 7, and the average of the apparent specific gravities so calculated shall be reported as that of the stone.

NOTE.—To determine the weight of the dry stone in pounds per cubic foot, the apparent specific gravity is multiplied by 62.4.

TENTATIVE METHODS OF TESTING INSULATING VARNISHES[1]

A.S.T.M. Designation: D 115 – 30 T

This is a **Tentative Standard**, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1921; Revised, 1922, 1923, 1924, 1925, 1926, 1928, 1929, 1930.

Scope.

1. These tests are intended for varnishes which are applied by brushing, dipping or spraying, and are primarily for the purpose of providing electrical insulation.

SPECIFIC GRAVITY

Specific Gravity.

2. The specific gravity shall be measured with a pycnometer Westphal balance or with a hydrometer so graduated that the specific gravity can be determined to 0.001. The temperature of the varnish shall be not less than 18° C. (64.4° F.) nor more than 22° C. (71.6° F.) and corrected to 20° C. (68° F.) by applying a correction of 0.0007 per 1° C. (0.0004 per 1° F.).

VISCOSITY

Viscosity.

3. The viscosity shall be determined at 20° C. (68° F.) and the results shall be stated in terms of absolute viscosity — poise[2] or centipoise (centipoise = 0.01 poise).

Note 1.—When measurements are made by an indirect method, the instrument used must be standardized. Oils of standard viscosity for use in standardizing such instruments can be obtained from the U. S. Bureau of Standards.

Note 2.—A description of the MacMichael viscosimeter as remodeled and improved for varnish testing together with directions for its calibration in absolute units appears in Appendix I.

FLASH POINT

Procedure for Flash Point.

4. The flash point shall be determined in accordance with the Standard Method of Test for Flash Point of Volatile Flammable

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electric Co., Schenectady, N. Y.

[2] The absolute viscosity of a material or its viscosity in absolute units (c.g.s., poises) has been defined as the force in dynes required to move, at a velocity of 1 cm. per second, one surface having an area of 1 sq. cm. past another parallel like surface 1 cm. away, overcoming the resistance to shear of the material filling the space between.

Liquids (A.S.T.M. Designation: D 56) of the American Society for Testing Materials.[1]

TIME OF DRYING

Test Specimen. 5. (*a*) Specimens for this test shall be pieces of thoroughly cleaned, smooth sheet copper or brass about 3 cm. (1.18 in.) wide and 20 cm. (7.88 in.) long and about 0.127 mm. (0.005 in.) thick.

(*b*) The specimen shall be dipped once in the varnish at a room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The consistency of the varnish shall be first so adjusted by trial that, when dry as determined in accordance with Section 7, the average thickness of the film of varnish on each side of the metal shall be between 0.022 and 0.026 mm. (0.0009 and 0.001 in.) Care shall be taken before dipping the specimens that the varnish has stood in the dipping tank for a sufficient length of time to be free from air bubbles.

Procedure. 6. (*a*) Specimens of air-drying varnish shall be dried in dust-free air at a room temperature of approximately 20° C. (68° F.).

(*b*) In the case of baking varnishes, six specimens shall be dipped and allowed to drain at a room temperature of approximately 20° C. (68° F.) until the varnish is set as indicated when the impression left on the surface by pressing lightly thereon with a finger will not become obliterated by further flow of the material. They are then to be dried in dust-free air in an oven at 105 to 110° C. (221 to 230° F.). At the end of the first 30 minutes, and again at the end of each 10-minute period thereafter, one specimen shall be taken from the oven and examined. In the case of slow-drying varnishes, this 10-minute period may be lengthened at the discretion of the operator.

NOTE.—The size of oven and the amount of ventilation have a considerable effect on the drying time of varnishes. For this reason the analytical type of electrically-heated oven should be used.

Time of Drying. 7. The varnish shall be considered dry when a piece of kraft paper 38 mm. (1.49 in.) in width and 152 mm. (6 in.) in length and approximately 0.063 mm. (0.0025 in.) in thickness does not adhere to the varnish when it is pressed on the surface of the varnish for one minute by a cylindrical 1-lb. weight, 1 in. in diameter. The kraft paper shall be applied in the vicinity of the center of the specimen and at right angles to it. The test shall be made at a temperature of approximately 20° C. (68° F.).

NOTE.—Certain types of varnishes dry with what is commonly known as a "tack"; but these types are rare. However, when testing them for drying time, it will be found that the kraft paper adheres to the varnish film and offers a certain amount of resistance to removal. On continued drying, the resistance to removal reaches constancy and is not changed by further drying. Therefore, the drying time is reported as the number of hours required to first reach constancy and the varnish should be reported as drying with a "tack."

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 362.

DIELECTRIC STRENGTH TEST[1]

Scope.

8. This test is intended to determine the suitability of an insulating varnish for use in certain electrical applications by taking the dielectric strength test under different conditions of temperature and after immersion in water. The test provides for the determination of dielectric strength under the following conditions:

(*a*) At room temperature (approximately 20° C.) in air.

(*b*) At 75° C. in air.

(*c*) At room temperature after immersion in water of approximately 20° C. (68° F.) for a period of 24 hours.

NOTE.—Dielectric strength determinations may also be made at room temperature and at 75° C. in oil. With this exception the procedure for test is the same as outlined here. If tests are made in oil this fact must be definitely reported with the results.

Test Specimens.

9. (*a*) Specimens for the dielectric strength test shall be prepared by dipping pieces of kraft paper about 20 cm. (7.88 in.) square and about 0.076 mm. (0.003 in.) in thickness into the varnish which shall be at the consistency specified in Section 5 (*b*).

NOTE.—The paper used shall be that which is commercially known as No. 1 sulfate kraft. The surface of the paper shall be smooth, free from pimples or lumps and reasonably free from hairy fibers. The paper shall also be free from conducting particles, slime spots, creases, cuts, specks or other "paper defects."

(*b*) Each specimen shall be dipped twice, as specified in Section 5 (*b*), once in each direction, in order to give a more uniform thickness of coating. The specimen shall be dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish shall be dried in dust-free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period six times that determined in accordance with Section 7.

(*d*) Specimens of baking varnish shall be drained and then baked in dust-free air at a temperature of 105 to 110° C. (221 to 230° F.) after each dip for a period three times that determined in accordance with Section 7.

(*e*) The final thickness of the specimen shall be 0.152 mm. (0.006 in.) to within ± 15 per cent.

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[1] **This test is relative only, but it gives more uniform results than those obtained with a copper base. See Appendix II for a procedure for determining the dielectric strength on a copper base, p. 1187.**

Procedure. 10. (*a*) The dielectric strength of the specimen shall be determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage shall be increased uniformly to breakdown in approximately 20 seconds. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the specimen is to be determined as close to the point of puncture as practicable.

NOTE.—When necessary, in order to get ten punctures additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined by the American Institute of Electrical Engineers,[1] and the voltage shall be measured by methods approved by the same organization.

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 100 volts. The apparatus shall comply with the standards of the American Institute of Electrical Engineers.[1]

Test Conditions. 11. The dielectric strength shall be determined under the following conditions:

(*a*) At room temperature (approximately 20° C.) in air.

(*b*) At 75° C. in air.

NOTE.—The tests at 75° C. shall be made in air in an analytical type of electrically-heated oven. The electrodes shall be at oven temperature before the test is started. Tests should be started 15 minutes after the specimen has been introduced into the oven and placed between the electrodes and completed before 15 minutes additional have elapsed.

(*c*) At room temperature on specimens which shall have been immersed in water at a room temperature of approximately 20° C. (68° F.) for a period of 24 hours.

NOTE 1.—Upon removal from the water, the surface water shall be wiped off and dielectric strength test made immediately.

NOTE 2.—Dielectric strength determinations may also be made at room temperature and at 75° C. in oil. With this exception the procedure for test is the same as outlined above. If tests are made in oil this fact must be definitely reported with the results.

Report. 12. In reporting the results for each of the three tests made as described in Section 11, the total voltage at puncture, the thickness of the specimen and the volts per mil of thickness shall be reported for each of the ten punctures together with the average, maximum and minimum values. In addition, the average dielectric strength in volts per mil of the test made at 75° C. and of the test made after water immersion shall be expressed as a percentage of that made at room temperature.

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[1] **Standards of the American Institute of Electrical Engineers.**

HEAT ENDURANCE TEST

Test Specimens.

13. (*a*) Specimens shall be prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or sheet brass about 20 cm. (7.88 in.) in length, 3 cm. (1.18 in.) in width and 0.127 mm. (0.005 in.) in thickness, into the varnish. The consistency of the varnish shall previously be adjusted by trial so that, when dry as determined in accordance with Section 7, the average thickness of the film of varnish on each side of the metal shall be between 0.022 and 0.026 mm. (0.0009 and 0.001 in.).

(*b*) Each specimen shall be dipped in the varnish at room temperature of approximately 20° C. (68° F.) and withdrawn slowly and uniformly (about 38 cm. (15 in.) per minute). The varnish shall be allowed to dry in the air (if an air-drying varnish) or baked in an oven at 105 to 110° C. (221 to 230° F.) (if a baking varnish) until dry as determined in accordance with Section 7. As soon as the first coat of varnish is dry, and the specimen is at room temperature, it shall be dipped again in the varnish in the reverse direction so as to give a uniform thickness of coating. The second coat of varnish shall be allowed to dry in the same manner as the first coat. When the second coat of varnish is dry, the specimen shall be measured. The thickness of varnish on each side of the metal shall be between 0.044 and 0.052 mm. (0.00173 and 0.00205 in.).

Procedure.

14. (*a*) The specimens shall be placed in a uniformly-heated oven, in which the temperature is maintained at 105 to 110° C. (221 to 230° F.). A specimen shall be removed at the end of the first 24 hours and every 24 hours thereafter.

(*b*) Each specimen, after heating, shall be tested at room temperature of approximately 20° C. (68° F.) by bending it through 180 deg. around a rod 0.32 cm. (0.125 in.) in diameter.

Report.

15. The number of hours of baking of the specimen which first showed cracking of the varnish film shall be reported, together with the make and type number of the oven used.

NOTE.—The size of oven and the amount of ventilation have a considerable effect on the heat endurance of varnish films. For this reason the analytical type of electrically-heated oven should be used.

OIL PROOF TEST

Oil Test Specimen. 16. (*a*) To test for the effect of oil, the specimens shall be prepared as prescribed in Section 13 (*a*).

(*b*) The specimens shall be dipped and dried as prescribed in Section 9 (*b*), (*c*) and (*d*).

Procedure. 17. The effect of oil on the varnish shall be determined by immersing the specimens in transformer oil at a temperature of 105 to 110° C. (221 to 230° F.) for 48 hours and noting the effect on the varnish as indicated, for example, by wiping with a piece of dry white cloth.

NOTE.—Incipient disintegration of the surface of the varnish may sometimes be detected by examining the oil for turbidity. If a specimen of the used oil filtered through filter paper can be distinguished from an unfiltered sample of the used oil, when the two samples in identical containers are held in front of a diffused light, the oil is turbid.

DRAINING TEST

(ALSO KNOWN AS "WORKING VISCOSITY" TEST)

Test Specimen. 18. A strip of bond paper 0.064 mm. (2.5 mils) in thickness, 10.2 cm. (4 in.) in width and 50.8 cm. (20 in.) in length, shall be immersed in the varnish at a room temperature of approximately 20° C. (68° F.) up to a line previously drawn across the paper a few inches from the top. The paper shall be withdrawn at a slow and uniform rate (about 38 cm. (15 in.) per minute), care being taken that the varnish is free from air bubbles. The specimen shall be permitted to drain thoroughly at room temperature while suspended in a vertical position. It shall then be dried or baked (according to the type of the varnish) until dry as determined in accordance with Section 7.

Measurements. 19. The thickness of the specimen in mils shall be measured at points 5.1 cm. (2 in.), 17.8 cm. (7 in.) and 30.5 cm. (12 in.), respectively, from the line to which the specimen was immersed.

Report. 20. The thickness of each film in mils at the three points specified in Section 19 shall be recorded. The difference between the thickness at the upper point (5.1 cm.) and that at the lower point (30.5 cm.) shall be taken as a measure of the variation in the film thickness caused by draining.

EVAPORATION TEST

Procedure. 21. One hundred cubic centimeters of the varnish shall be placed in a flat-bottom crystallizing dish approximately 75 mm. (2.95 in.) in diameter and 45 mm. (1.77 in.) in height. It shall be heated to a temperature of 100° F. ± 2° F. (37.8° C. ± 1.1° C.) for a period of 7 hours, the sample being exposed to still air in the open room.

22. The decrease in volume of the sample shall be taken as the evaporation, this decrease being determined by noting the amount of water or kerosine that must be added to fill the dish to the original level. **Evaporation.**

NOTE.—This test is relative only. That is, it is only suitable for comparing one varnish with another when the tests are made simultaneously under exactly the same conditions.

TEST FOR NON-VOLATILE MATTER BY WEIGHT

23. A portion of the sample shall be placed in a stoppered bottle or weighing pipette and weighed. About 1.5 g. of the sample shall be transferred to a weighed flat-bottom metal dish about 8 cm. (3.15 in.) in diameter, such as the cover of a friction-top tin can. The container shall again be weighed and the exact weight of the portion of the sample transferred to the weighed dish calculated by difference. The dish with its contents shall be heated for three hours in an oven maintained at 105 to 110° C. (221 to 230° F.). It shall then be weighed after cooling. **Procedure.**

24. The ratio of the weight of the residue to the weight of the original sample expressed as a percentage shall be taken as the percentage of non-volatile matter by weight in the varnish. **Non-Volatile Matter.**

TEST FOR VOLATILE MATTER BY VOLUME

25. This test is intended to determine the volume percentage of volatile matter (solvent) in a varnish, and to afford a means of arriving at the volume composition of the varnish with respect to volatile (solvent) and non-volatile (base) constituents. **Scope.**

26. (*a*) About 100 cc. of the varnish shall be distilled in accordance with the Standard Method of Test for Distillation of Gasoline, Naphtha, Kerosine, and Similar Petroleum Products (A.S.T.M. Designation: D 86) of the American Society for Testing Materials.[1] The distillation shall be "qualitative" instead of "quantitative" as given in Section 9 of the Standard Method D 86; that is, it is not necessary to record the volume of distillate recovered, or the temperature of the initial boiling point or end point. **Procedure.**

(*b*) The distillation shall be continued until a suitable end point indicates that all the volatile matter (solvent) has been distilled off.

NOTE.—In the distillation of varnishes the end point differs with the various types and compositions. In all cases, however, the rate of distillation slows down as the end point is approached; and, when the end point is reached, acrolein (formed in the decomposition of the varnish base) is evolved and may be detected by its characteristic odor.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 491.

In addition to the evolution of acrolein, the following phenomena are suitable indicators of end point:

(1) When the end point of the solvent is considerably lower than the initial boiling point of the base, the end point of the distillation is indicated by the temperature reaching a maximum and then starting to fall consistently.

(2) When the end point of the solvent and the initial boiling point of the base are too close, or overlap, the above temperature drop does not occur. The end point of the distillation is then indicated by a sudden foaming up of the residual base in the distillation flask; or, if the distillation has been accompanied by foaming, the end point is indicated by a breaking of surface tension with a consequent cessation of foaming.

Specific Gravity. 27. The specific gravity of the volatile matter (solvent) recovered by distillation shall be determined in accordance with the procedure described in Section 2.

Volatile Matter by Weight. 28. The difference between 100 per cent and the percentage of non-volatile matter determined in Sections 23 and 24 shall be calculated and recorded as the percentage of volatile matter by weight.

Volatile Matter by Volume. 29. The percentage of volatile matter by volume shall be calculated from the formula:

$$x = \frac{AC}{B}$$

where

x = the percentage of volatile matter by volume;
A = the specific gravity of the original varnish, as determined in Section 2;
B = the specific gravity of the volatile matter (solvent) recovered by distillation, as determined in Section 27; and
C = the percentage of volatile matter by weight, as determined in Section 28.

Accuracy. 30. With proper care and attention to detail in making this test, differences occurring between different laboratories should not exceed 2 per cent for varnishes containing solvents which have end points not over 235° C. (455° F.), and should not exceed 4 per cent when the end point of the solvent is as high as 307.2° C. (585° F.).

DIELECTRIC STRENGTH OF VARNISH IN THE LIQUID STATE

Scope. 31. The purpose of the dielectric strength test of varnish in the liquid state is to insure that the varnish is free from moisture and foreign matter such as might come from unclean shipping containers.

Apparatus. 32. The apparatus shall be as described in Section 14 of the Standard Methods of Testing Molded Insulating Materials (A.S.T.M. Designation: D 48) of the American Society for Testing Materials.[1] The test cup for holding the sample of varnish shall be made of a material having a suitable dielectric strength. It must be insoluble in and unattacked by mineral oil and gasoline and non-absorbent so far as moisture, mineral oil and gasoline are concerned. The electrodes in the test cup between which the sample is tested shall be circular disks of polished brass or copper, 1 in. in diameter and having square edges. The electrodes shall be mounted in the test cup having their axes horizontal and coincident, with a gap of 0.1 in. between their adjacent faces, and with top of electrodes about 33 mm. ($1\frac{1}{4}$ in.) below the top of the cup.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 980.

Procedure.

33. (*a*) The electrodes and the test cup shall be wiped clean with dry calendered tissue paper or with a clean dry chamois skin, and thoroughly rinsed with a suitable solvent such as dry benzol or redistilled carbon tetrachloride. The electrodes and test cup shall then be rinsed with some of the varnish to be tested.

(*b*) The spacing of electrodes shall be checked with a standard round gage having a diameter of 0.100 in. and the electrodes then locked in position. Care shall be taken not to touch the electrodes with the gage or in any other manner after cleaning the electrodes and cup, so as to avoid any possible contamination.

(*c*) The temperature of the varnish when tested shall be the same as that of the room, which should be between 20 and 30° C. (68 and 86° F.).

(*d*) The sample of the varnish shall be shaken so that it will be thoroughly mixed before filling the test cup, the shaking shall be done gently to avoid the formation of bubbles.

(*e*) The cup shall be filled with varnish to a height of not less than 20 mm. (0.787 in.) above the top of the electrodes.

(*f*) The varnish shall be allowed to remain in the test cup until all air bubbles have disappeared.

(*g*) Voltage shall be applied and increased uniformly at the rate of approximately 3 kv. (r.m.s. value) per second until electrical breakdown occurs as indicated by a continuous discharge across the gap. (Occasional momentary discharges which do not result in a permanent arc may occur; these should be disregarded.)

(*h*) After the breakdown and before removing the varnish from the test cup, the electrode surfaces shall be rubbed thoroughly with dry calendered tissue paper wrapped around a knife blade to provide stiffness. The test cup shall then be emptied and immediately refilled with the next filling of varnish to be tested.

(*i*) Five fillings shall be tested in conformity with the above procedure and the last filling of the cup shall drain the sample container.

Variations in Results. 34. Differences as great as 15 per cent may occur between different laboratories in the results of this test. This is considered satisfactory in view of the purpose of the test.

Report. 35. The report shall include the following:

(*a*) The kilovolts (r.m.s. value) at each electrical breakdown;

(*b*) The average value of the 5 breakdowns in kilovolts; and

(*c*) The mean deviation from the average value expressed as a percentage of the average breakdown value.

APPENDIX I

DESCRIPTION AND USE OF REMODELED MACMICHAEL VISCOSIMETER FOR DETERMINING VISCOSITY OF INSULATING VARNISHES

APPARATUS

The viscosity of varnishes may be determined by means of the remodeled MacMichael Viscosimeter shown in Figs. 1, 2 and 3. This instrument gives the viscosity values in terms of MacMichael degrees which are converted into absolute units of viscosity (centipoise) by means of the calibration curves of the various suspending wires.

In Fig. 1 the apparatus, consisting of the following parts, is shown unassembled:

A is the indicator by means of which the zero is adjusted and readings on scale *D* are taken.

B is the insulated wire suspension, the torsion of which measures the viscosity. The wire is fastened only at the bottom of its insulating sleeve *E′*. This is suspended by hanging it on points *P′*. (Ten wires of different size to cover various ranges of viscosities are supplied.)

C is the clamp screw which clamps the hollow spindle *E* to the sleeve *E′* which holds the torsion wire *B*.

D attached to hollow spindle *E* is the dial on which are calibrated the degrees MacMichael (300 deg. to the circumference). By means of this dial and indicator *A* the degrees deflection are determined as indicated in the method described below.

E is the hollow vertical spindle inside of which is the torsion wire sleeve *E′* which contains torsion wire *B*.

F is an oil-filled dash pot which acts as a brake to deaden oscillations and bring the suspension to rest quickly when making a determination. The dash pot swings between arm guides *F′* when the machine is assembled.

G is the steel disk which is attached to the bottom of vertical spindle *E*. Torsion wire *B* and *E′* is inserted into *E* and clamped with screw *C* and the disk *G* is then suspended in the liquid whose viscosity is being measured. Rotation of the sample cup *H* rotates the liquid and the rotating liquid exerts a certain force on the disk *G* partially rotating it and thus a torsion is produced in the wire suspension *B*, the deflection of which (or degree of torsion) is read from the scale on deflecting disk *D*.

H is the container which holds the sample. A locking device fastens it securely to *I* or *J*.

I is the water bath used for securing a uniform temperature in the liquid whose viscosity is being determined, when these viscosity measurements are desired at temperatures approximating that of the room (used on varnishes and oils).

J is the heating unit which is used in place of *I* when viscosity measurements are made at high temperatures (used on compounds).

K is the contact which carries the electric current to the heating unit cup *J*. It can be swung back when using cups *H* and *I* and when therefore electric heating is not desired.

L is the counter which determines the speed of the motor by counting the revolutions of turntable *M*. A trip arrangement allows this counter to be lowered or raised, thus throwing the counter in or out of operation at will.

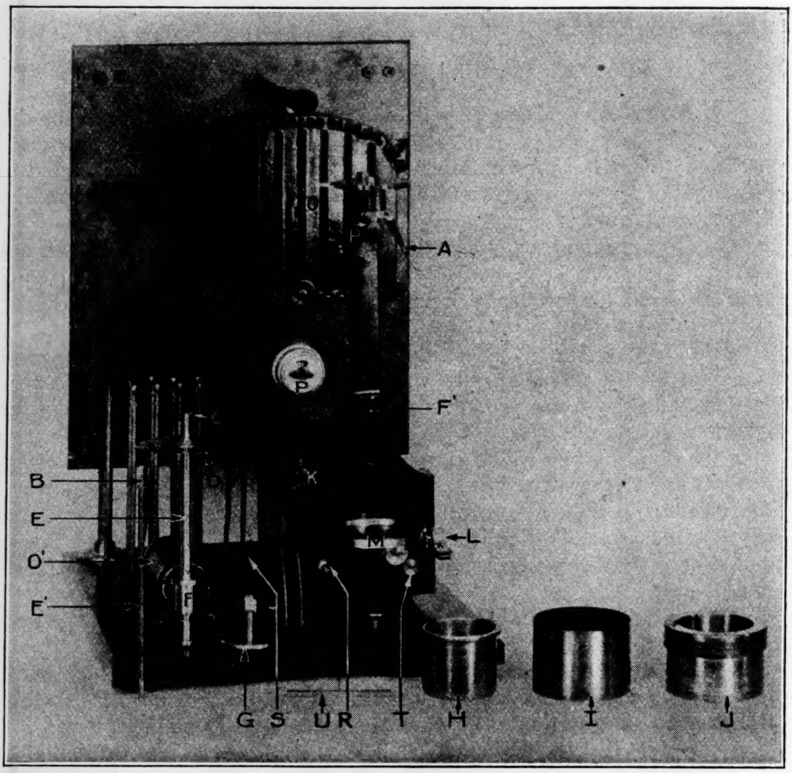

FIG. 1.—Improved MacMichael Viscosimeter Apparatus, Unassembled.

M is the rotating turntable in which *I* or *J* are set. A locking device (not shown) locks *I* or *J* securely to the turntable *M* so that when the turntable rotates the water bath or heating unit with the sample container also rotate.

N is the inclosing case under which is the motor and governor shown in Fig. 3. These operate turntable *M*.

O is a rheostat which controls the current going to the heating unit *J*.

O' is a rheostat controlling current for motor (shown only on remodeled instruments).

P is the knife switch (snap switch on new type machine) controlling the current for the heating unit *J*.

R is the knife switch (push button on new type machine) which controls the electric current operating the motor shown in Fig. 3.

S is a leveling screw to level the instrument. Another such screw (not shown) is directly opposite to this one.

T is the governor screw that adjusts the speed of the motor by adjusting the governor shown in Fig. 3. In the remodeled apparatus the speed of rotation of turntable *M* can be decreased by moving the large gear in gear box away from the motor until pin of motor shaft is disengaged from slot of gear sleeve.

U is the measuring device used to measure the depth of the liquid in container *H*.

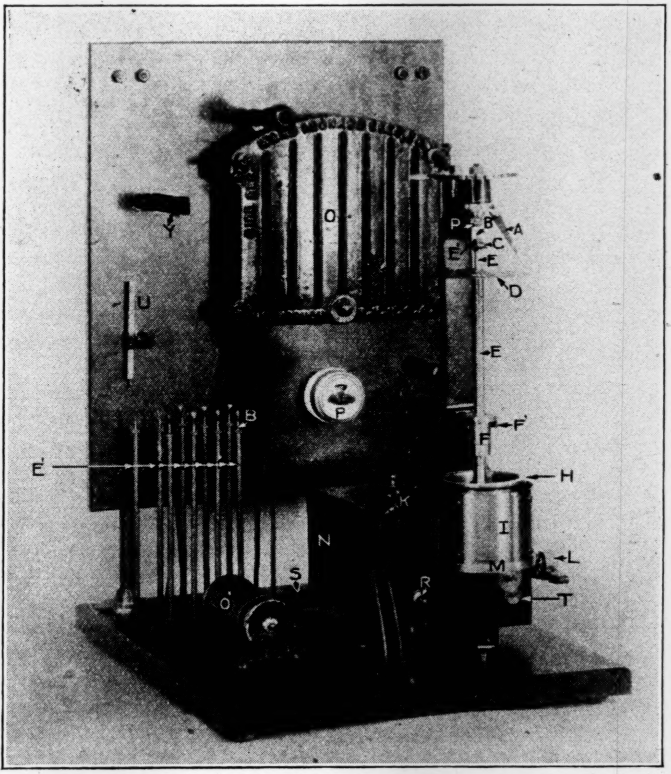

FIG. 2.—Improved MacMichael Viscosimeter Apparatus Assembled for Testing Varnish or Oil.

p are the projecting points on which the assembled spindle, namely, insulated torsion wire suspension *B* and *E'*, spindle and deflection dial *D*, and immersed disk *G* are suspended.

The apparatus is shown assembled in Fig. 2 for viscosity determinations on oil or varnish. Explanatory letters refer to the same parts as in Fig. 1.

In Fig. 3 are shown the internal structure and cup and heating unit assembled for testing compounds. The explanatory letters refer to the following:

V is the motor which operates the turntable *M*.

W is the governor controlling the speed of the motor.

X are the leads to connect instrument to 110-volt alternating current lighting circuit (only on remodeled machines).

Y is the clamp holder for holding the spindle *E* with its dial *D*, when the machine is not in use (remodeled machines).

The heating unit *J* and the sample container, *H*, are here shown assembled as used in the viscosity determinations on compounds.

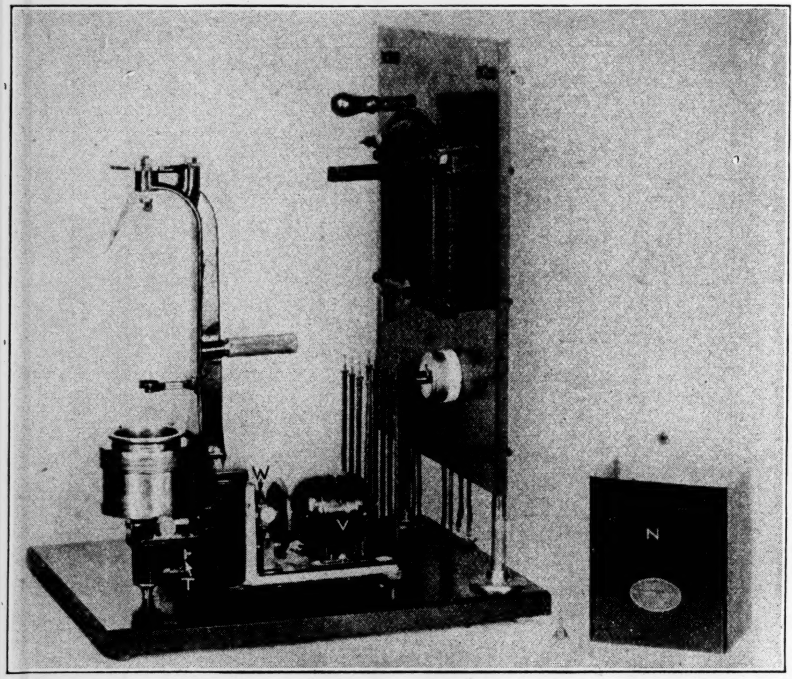

FIG. 3.—Improved MacMichael Viscosimeter Apparatus Showing Internal Structure and Cup and Heating Unit for Testing Compounds.

DIRECTIONS FOR MAKING VISCOSITY MEASUREMENTS ON VARNISH

Cups and disks must be perfectly clean. Otherwise reliable results cannot be obtained.

Dash pot *F* on the stem of the spindle should be two-thirds full of a medium grade of good machine oil (Etna Engine or Appollo) in order to dampen vibrations.

Use water bath *I* to secure and maintain the temperature of the sample in *H* when testing varnishes or oil.

Insert container *H* into water bath *I*. See that they are properly locked together, then lock bath *I* on turntable *M*.

Choose the proper torsion wire suspension for the liquid to be tested. Experience is the best guide to determine what suspension to use. Screw the disk *G* to the spindle *E*, and insert into *E* the proper insulated torsion wire suspension *E'*. Suspend these assembled parts from points *p* so the disk is suspended in the container *H*. Be sure to always suspend the wire on the points *p* with the flat side of the triangular button against the flat side of the supporting arm. The rounded surface of the triangle must face out towards the operator. Tightly fit the cover of the dash pot *F* on the arm guides F'.

See that the instrument is perfectly level. Use leveling screws *S* to adjust the instrument. The instrument is level when the suspended sleeve *E* swings exactly in the center of the hole of the cover on the dash pot.

Adjust the speed of the motor to 60 r.p.m. This should be checked each time determinations are made. Use the governor screw *T* to adjust the speed of the motor. The gear in the gear box, referred to under *T* in the description of Fig. 1, should be in high speed position, that is, towards the motor. Use a stop watch to adjust the speed. After the speed is adjusted, lower the counter *L* so it will not operate during the following procedure.

NOTE.—The deflection is directly proportional to the speed of rotation. The 60 r.p.m. must therefore be maintained when the varnish, oil or compound is in the cup. It is, therefore, necessary to check first the revolutions per minute without the disk suspended in the sample, and again, when running a determination with the disk suspended in the sample. The motor must give the same number of revolutions per minute in each case and this valve must be the same as was used for calibrating the suspension.

When the instrument is level adjust the indicator *A* to the zero mark on the dial *D* by moving the indicator as necessary. When the indicator has been set it must not be moved again until the test has been completed.

Fill the container *H* with the sample to be tested to a depth of 3.5 cm. A special device *U* is provided to measure this depth. Lay this device across the cup so the pointed end projects into the cup. When the surface of the liquid just touches the point, the depth of the liquid in the cup is 3.5 cm.

Raise or lower the temperature of the oil or varnishes to 21° C. by adding hot or cold water to the water bath, always stirring the sample well until a uniform temperature is secured. This is imperative. The sample may be stirred by rotating the sample cup frequently. It may also be stirred by lifting the spindle from the points *p* and stirring with the disk *G* holding the spindle by the barrel *E* and stirring by giving the disk an up-and-down movement in the sample cup. In the case of compounds, it is necessary to stir in this manner. In testing varnishes and oils, usually sufficient stirring can be obtained by rotating the cup while holding the barrel *E* to keep the disk stationary. If the spindle is removed from the points *p* it must always be suspended again with the same flat side of the supporting triangular button against the supporting arm so that the zero position is not changed.

If, when resuspending the spindle from points *p* it is noted that the zero point has moved, do not reset the indicator *A* as the change probably is due to some torsional effect produced by the sample. This may be especially noticed when testing compounds. Rotate the cup and take the reading without resetting the indicator.

When reading the thermometer have the bulb in the sample midway between the disk and the container wall and not resting on the bottom. Test the temperature at various points in the container to determine if a uniform temperature has been secured.

When a uniform temperature of 21° C. is secured, start the cup rotating by closing the switch *R*. Keep a hand on the switch and watch the scale on the disk *D*. If there is any danger that the deflection will go beyond the maximum limit for the suspension being used, open the switch immediately. Insert the next strongest wire suspension into the spindle and repeat as above indicated. When changing suspensions it is necessary to again set for zero. This may be accomplished without removing the sample, by simply removing the water bath, *I*, with its sample container, *H*, and then suspending the spindle with its new suspension on *p*, and leveling and adjusting as described above. It is necessary, of course, to thoroughly clean the disk, *G*, when doing this for if any varnish film should dry on the disk, the uneven or rough surface thus produced on the disk would cause an erroneous reading. A suspension wire should never be allowed to deflect beyond its maximum limit, for beyond this point a permanent set would be produced in the wire and a new calibration of the wire would have to be made or probably a new wire would have to be used. Table I gives a maximum and minimum limit for suspensions now in use. If the deflection is less than this minimum limit the next weakest suspension must be inserted and the test repeated. The reason for this is that at low deflections a change in slope appears on the calibration curve of the MacMichael degrees *versus* centipoises. The percentage error is magnified here and hence a reading that comes up higher in the calibration curve should be used. The maximum limit given may not be the limit to which it is permissible to deflect the wire in order to prevent its acquiring a permanent set. It, however, happens to be the limit of the calibration curve available for that suspension when the wire was calibrated.

TABLE I.—MAXIMUM AND MINIMUM LIMITS FOR SUSPENSIONS.

SUSPENSION NUMBER	MINIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING	MAXIMUM DEFLECTION, DEG. MACMICHAEL	APPROXIMATE EQUIVALENT CENTIPOISE READING
A (Weakest)	30	18	125	89
B	20	35	100	200
C	7.5	30	35	175
D	5	70	32.5	400
E	10	200	45	975
F	5	225	40	1800
G	10	750	50	4200
H	4	700	24	4000
I	2	750	11	4000
J (Strongest)	1	1375	5	5500

Record the deflection in degrees MacMichael and read the viscosity in centipoises from the calibration curve of the suspension used.

NOTE 1.—Before any sets of suspensions are used, they must be calibrated as noted under heading "Calibration of Suspensions."

NOTE 2.—The following table gives the diameter of the wires (new American music wire gage) used in making the suspensions and the maximum limit of torsion in degrees MacMichael to which they may be subjected before they acquire a permanent set:

SUSPENSION NUMBER	DIAMETER WIRE, IN.	TORSIONAL LIMIT, DEG. MACMICHAEL
A (Weakest)	0.010	125
B	0.013	118
C	0.016	110
D	0.020	102
E	0.024	92
F	0.029	81
G	0.033	73
H	0.041	55
I	0.049	35
J (Strongest)	0.063	5

NOTE 3.—Not all of the suspensions noted above are required in testing varnish, Suspensions E, F, and G will be sufficient for practically all varnishes. The heavier wires H, I and J are used for very viscous materials.

CALIBRATION OF SUSPENSIONS.

In order to calibrate the torsion wire suspensions used in this apparatus to measure viscosity, a number of samples of oil and a sample of pure castor oil should be prepared and sent to the U. S. Bureau of Standards for determination of absolute viscosity at various temperatures. The following are typical data as supplied by the Bureau of Standards on four standard samples of oil:

OIL SAMPLE	TEMPERATURE, DEG. CENT.	VISCOSITY, CENTIPOISES
No. 1. Mineral Oil (Transformer) 63 seconds Saybolt viscosity at 100° F.	10	29.95
	20	18.6
	30	12.44
No. 2. Mineral Oil (Transformer) 104 seconds Saybolt viscosity at 100° F.	10	72.50
	20	41.02
	30	25.40
No. 3. Mineral Oil (Lubricating) 297 seconds Saybolt viscosity at 100° F.	10	405
	20	169.9
	30	89.64
No. 4. Castor Oil, U. S. P. (AA)	10	2693
	15	1704
	20	1104
	25	746

The viscosity of sample No. 1 is so low that even with the weakest suspension only a very small deflection is secured. As the percentage of error is higher at small deflections than at large deflections, such a sample should not be used. These samples must have their absolute viscosities checked at least once a year as it has been found that the oils undergo some change on standing over long periods.

The calibration of the wires is made by testing the standardized samples of oil, following the directions as given above under heading "Directions for Making Viscosity Measurement on Varnishes." Tests are made at the same temperatures as used by the Bureau of Standards for their absolute viscosity tests. The above standard samples would be used as follows:

	SUSPENSION NUMBER
Sample No. 2 at 10° C.—20° C.—30° C.	A, B, C, D, E and F
" " 3 " 10° C.—20° C.—30° C.	F
" " 3 " 20° C.—30° C.	C, D, E and F
" " 4 " 10° C.	H, I and J
" " 4 " 15° C.	G, H, I and J
" " 4 " 20° C.	F, G, H and I
" " 4 " 25° C.	F, G, H and I

The degrees MacMichael obtained for each suspension on each sample at each temperature are plotted against corresponding U. S. Bureau of Standards absolute viscosity figures (centipose) for those samples at the same temperatures and a line is drawn through these points. The line should be straight except possibly at low deflections where the error is correspondingly high.

Once every two months the suspensions should be recalibrated. In this recalibration the viscosities obtained as read from the plotted curve are compared with the Bureau of Standards viscosities and if they agree within 10 per cent, the curve need not be replotted. In cases of low viscosities 15 per cent error is allowable. If the majority check tests show a larger error, a new curve should be plotted for the suspension.

APPENDIX II

DIELECTRIC STRENGTH TESTS ON COPPER BASE

Where it is desired to make dielectric strength tests of solid films of varnish (as distinguished from the specimens prescribed in the methods, which are a combination of varnish and paper fibers), it is recommended that copper be used as the base as formerly required in the methods. The following are the directions for preparing and testing such specimens:

1. (*a*) Specimens are prepared by dipping pieces of thoroughly cleaned, smooth sheet copper or brass about 20 cm. (7.88 in.) square and about 0.127 mm. (0.005 in.) thick into the varnish which is at the consistency prescribed in Section 5 (*b*) of the methods.

(*b*) Each specimen is dipped twice, once in each direction, in order to give a more uniform thickness of coating. The specimen is dried after each dip in the same vertical position in which it was dipped.

(*c*) Specimens of air-drying varnish are dried in free air after each dip at a room temperature of approximately 20° C. (68° F.) for a period six times as long as that determined in accordance with Section 7 of the methods.

(*d*) Specimens of baking varnish are drained and then baked after each dip for a period three times as long as that determined in accordance with Section 7 of the methods.

(*e*) The final thickness of the film of varnish on each side of the specimen is between 0.044 mm. (0.0018 in.) and 0.052 mm. (0.002 in.).

2. (*a*) The dielectric strength of the two films of varnish is determined by applying alternating potential to two circular metal disks, 5.08 cm. (2.0 in.) in diameter and with edges rounded to a radius of 0.64 cm. (0.25 in.) which are placed in contact with the two sides of the specimen directly opposite each other and under a pressure of approximately 0.5 kg. (1.1 lb.). Starting at zero, the voltage shall be increased uniformly to breakdown in approximately 20 seconds. Ten such punctures are to be made at various points selected at random on each specimen. In each test the thickness of the films of varnish is to be determined as close to the point of puncture as practicable.

NOTE.—When necessary, in order to get ten punctures, additional specimens should be tested.

(*b*) The frequency of the test potential shall be not greater than 100 cycles per second, and each part of the testing apparatus shall have a continuous rating of not less than 2 kva. (preferably larger). The wave form shall be a sine curve as defined, and the voltage shall be measured by methods approved by the American Institute of Electrical Engineers.

(*c*) The voltage may be controlled by any approved method which does not distort the wave form beyond the limits prescribed above and which does not subdivide the voltage in steps greater than 500 volts. The apparatus shall comply with the Standards of the American Institute of Electrical Engineers.

3. The volts at puncture, the net thickness of insulation and the volts per mil of net thickness shall be reported for each of the ten tests together with the average maximum and minimum volts per mil.

TENTATIVE METHODS OF TESTING SHEET AND TAPE INSULATING MATERIALS FOR DIELECTRIC STRENGTH[1]

A.S.T.M. Designation: D 149 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1922; REVISED, 1923, 1924, 1926, 1927, 1930.

Scope. 1. These methods are designated to determine the dielectric strength of sheet and tape insulating materials except (*a*) rubber insulating tape, which should be tested in accordance with the Tentative Specifications for Rubber Insulating Tape (A.S.T.M. Designation: D 119 – 28 T) of the American Society for Testing Materials,[2] and (*b*) friction tape for electrical purposes which should be tested in accordance with the Standard Specifications for Friction Tape for General Use for Electrical Purposes (A.S.T.M. Designation: D 69) of the American Society for Testing Materials.[3]

Since the dielectric strength of sheet and tape materials is dependent upon the time of application of the electrical tension, two tests differing in time duration are included as *A*, Short-Time Dielectric Strength Test, and *B*, One-Minute Step-by-Step Dielectric Strength Test, respectively.

A third test, designated as an Endurance Dielectric Strength Test, is included under *C*. It shows the relative dielectric strength of different flexible sheet and tape insulating materials at high temperature when subjected to electrical tensions for relatively long periods.

It should be noted that the results obtained with the electrodes specified for sheet material will differ from those specified for tape material (Section 3) and will not be comparable because the apparent dielectric strength of thin materials varies with the area of the electrodes.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electric Co., Schenectady, N. Y.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 1068 (1928); also 1930 Book of A.S.T.M. Tentative Standards, p. 669.

[3] 1930 Book of A.S.T.M. Standards, Part II, p. 1036.

A. Short-Time Dielectric Strength Test

APPARATUS

High-Voltage Transformer.

2. (*a*) Any well-designed, high-tension transformer connected to an alternating current supply, having as nearly a true sine wave as possible, may be used. The transformer and the source of supply of energy shall be not less than 2 kva. for voltages of 50,000 volts or less, and not less than 5 kva. for voltages above 50,000 volts. The frequency shall not exceed 100 cycles per second.

(*b*) Regulation shall be so controlled that the high-tension testing voltage taken from the secondary of the testing transformer can be raised gradually from any point and in no case more than 500 volts at a step. The control may be made by generator field regulation, with an induction regulator, or with a variable ratio auto transformer. Any method of regulating the voltage is satisfactory which does not distort the wave more than 10 per cent from a sinusoidal shape.

(*c*) The voltage may be measured by any approved method which gives root-mean-square values, preferably by means of a voltmeter connected to a special voltmeter coil in the high-tension winding of the testing transformer, or to a separate step-down instrument potential transformer. A voltmeter on the low-tension side of the transformer is satisfactory, if the ratio of transformation does not change under any test condition. An electrostatic voltmeter properly calibrated in the high-tension circuit is also satisfactory. A spark gap may be used to check the readings at very high potentials.

(*d*) Some protection is desirable in the high-tension circuit of testing transformers where the potential is 25,000 volts or over, to prevent dangerous surges and limit the current when the test specimen is punctured. It is, however, desirable to have as much energy available as possible when puncture occurs. If impedance in the form of choke coils is used in series with the high-tension terminals, it should not be greater than that which will limit the high-tension current to double the normal rated current of the testing transformer.

When a spark gap is used, a non-inductive resistance of about one ohm per volt should be inserted in series with one terminal of the spark gap, to damp high-frequency oscillations at the time of breakdown and limit the current flow. This resistance shall be as near the gap as possible. If the test is made with one side grounded, this resistance shall be on the ungrounded side of the circuit, and if neither side is grounded, the resistance shall be inserted one-half on each side of the spark gap. Water tube resistors are preferable to carbon for this purpose, as carbon resistance may be materially decreased by the passage of current.

(*e*) The apparatus used and the method of measuring the voltage shall meet the requirements of the Standards of the American Institute of Electrical Engineers.

Electrodes. 3. The electrodes shall be of brass or copper with flat polished contact surfaces. For sheet material they shall be cylinders 2 in. (50.8 mm.) in diameter and 1 in. (25.4 mm.) in length with the edges rounded to a radius of $\frac{1}{4}$ in. (6.35 mm.). For tapes the electrodes shall be cylindrical rods $\frac{1}{4}$ in. (6.35 mm.) in diameter with edges rounded to a radius of $\frac{1}{32}$ in. (0.8 mm.) and the upper movable one shall weigh 0.1 lb. (45.4 g.) ± 0.005 lb. (2.3 g.).

TEST SPECIMENS

Test Specimens. 4. (*a*) The test specimens may be of any convenient size, but the total area of the specimens of one sample of material shall be sufficient to permit making at least ten satisfactory tests.

(*b*) The specimens shall be representative of the material to be tested, care being taken to select material which is free from abnormal defects such as blisters, wrinkles, cracks, etc.

PROCEDURE

Surrounding Medium. 5. The tests shall be made in air with the specimen at room temperature.

Condition of Electrodes. 6. The testing electrodes shall be kept clean and polished.

Position of Electrodes and Specimen. 7. The electrodes shall be self-aligning, and shall be placed exactly opposite one another with the specimen in a horizontal plane between them.

8. The edges of tapes shall be clamped between blocks of insulating material under a pressure of approximately 100 lb. per sq. in. to prevent flashover occurring before puncture.

NOTE.—In the Appendix are shown two different devices which have been found satisfactory for these tests.

Application of Voltage. 9. Starting at zero, the voltage shall be increased uniformly to breakdown at a rate of 0.5 kv. per second, except that if breakdown occurs at this rate in less than 40 seconds, the rate shall be decreased so that breakdown will occur in not less than 40 seconds. If the material fails at less than 5 kv., the minimum time shall be reduced from 40 seconds to 20 seconds.

Number of Tests. 10. Ten tests shall be made and the average of these ten puncturing voltages shall be taken.

Thickness. 11. The thickness of the specimen shall be measured at each puncture, using a ratchet micrometer graduated to 0.001 in. and having a circular foot not less than 0.240 in. nor more than 0.260 in. in diameter.

Report.

12. The report shall include the following:

(*a*) The thickness of the specimen at each puncture;

(*b*) Total volts and volts per mil of thickness at each puncture;

(*c*) The average, maximum and minimum volts at puncture per mil of thickness for each sample;

(*d*) The room temperature;

(*e*) The relative humidity, in per cent;

(*f*) The duration of the test.

B. One-Minute Step-by-Step Dielectric Strength Test

APPARATUS

Apparatus.

13. The apparatus shall consist of the high-voltage transformer and the electrodes specified in Sections 2 and 3.

TEST SPECIMENS

Test Specimens.

14. The test specimens shall be as specified in Section 4.

PROCEDURE

Surrounding Medium.

15. The tests shall be made in air with the specimen at room temperature.

Condition of Electrodes.

16. The testing electrodes shall be kept clean and polished.

Position of Electrodes and Specimen.

17. The electrodes shall be self-aligning, and shall be placed exactly opposite one another with the specimen in a horizontal plane between them.

18. The edges of tapes shall be clamped between blocks of insulating material under a pressure of approximately 100 lb. per sq. in. to prevent flashover occurring before puncture.

NOTE.—In the Appendix are shown two different devices which have been found satisfactory for these tests.

Application of Voltage.

19. An initial voltage shall be applied equal to 40 per cent of the breakdown voltage in the short-time test, adjusted as shown in the following table. The voltage shall then be increased in increments as indicated in the table, up to failure, being held at each step for one minute. The change from each step to the next higher shall be made within 10 seconds.

BREAKDOWN KILOVOLTS BY SHORT-TIME METHOD	ADJUST 40 PER CENT OF BREAKDOWN VOLTAGE TO NEAREST	INCREMENT OF INCREASE
12.5 kv. or less	0.5 kv.	0.5 kv.
over 12.5 to 25 kv., inclusive	1.0 "	1.0 "
over 25 " 50 " "	2.5 "	2.5 "
over 50 " 100 " "	5.0 "	5.0 "
over 100 "	10.0 "	10.0 "

NOTE.—*Example:*

Breakdown voltage by short-time method = 41 kv.
40 per cent of breakdown voltage = 16.4 kv.
Initial voltage obtained by adjusting 40 per cent of breakdown voltage to nearest 2.5 kv. = 17.5 kv.
Voltage will be increased in increments of 2.5 kv.
Therefore, second step = 20.0 kv., etc.

Number of Tests. 20. Five tests shall be made and the average of these five puncturing voltages shall be taken.

Thickness. 21. The thickness of the specimen shall be measured at each puncture, using a ratchet micrometer graduated to 0.001 in. and having a circular foot not less than 0.240 in. nor more than 0.260 in. in diameter.

Report. 22. The report shall include the following:

(*a*) The thickness of the specimen at each puncture;

(*b*) Total volts and volts per mil of thickness at each puncture;

(*c*) The average, maximum and minimum volts at puncture per mil of thickness for each sample;

(*d*) The room temperature;

(*e*) The relative humidity, in per cent;

(*f*) The duration of the test;

(*g*) The value of the initially applied voltage and the value of the voltage at each step.

C. Endurance Dielectric Strength Test

APPARATUS

Apparatus. 23. The apparatus shall consist of the high-voltage transformer specified in Section 2.

Test Specimen. 24. (*a*) The specimens shall be made by wrapping the material, in tape form with one-quarter lap, one-half lap, butt jointed or as sheets, on brass tubes. The tubes shall be, for sheets and for tape up to 1½ in. in width, about 36 in. in length and 1 in. in outside diameter. For tapes wider than 1½ in., the tubes shall be 2 in. in outside diameter. The sample shall be built up to the desired thickness, simulating practical conditions, winding all layers of tape in the same direction.

(*b*) A smooth layer of metal foil shall then be wrapped over the insulation for a distance of 24 in., leaving 6 in. of insulation uncovered at each end of the tube. The metal foil shall be bound in place with a wrapping of adhesive tape and shall extend the full length of the tube in order to protect the insulation at the end from corona discharge.

(*c*) A thermocouple shall be applied to the metal foil near the center of the tube and held in place by the adhesive tape.

PROCEDURE

Position of Specimen.

25. The specimen shall be mounted in an oven and a temperature of 100° C. (212° F.) maintained during the test. Provision shall be made for so mounting the specimen that the tube may be connected to the high voltage side of the circuit with the metal foil sheath and thermocouple connected to ground.

Application of Voltage.

26. A voltage equal to 10 per cent of the breakdown voltage (to the nearest kilovolt) obtained in the short-time test (Test *A*) shall be applied and maintained for 30 minutes. The voltage shall then be increased by steps of 20 per cent of the initial value until puncture occurs, the voltage being held at each step for 30 minutes.

Temperature Readings.

27. The temperature of the sample as indicated by the thermocouple shall be observed at intervals during the test and recorded at the end of each 30-minute period. It will be found that the temperature rises gradually until just before breakdown when the temperature increases rapidly. During this latter period, temperature readings shall be recorded at frequent intervals.

Report.

28. (*a*) The results shall be plotted using time, expressed in hours, as abscissas, and temperature, in degrees Centigrade, as ordinates. In addition to time as abscissas, the values of applied kilovolts shall be indicated since the value of kilovolts increases uniformly with time. The significant values to be taken from the curve and reported are:

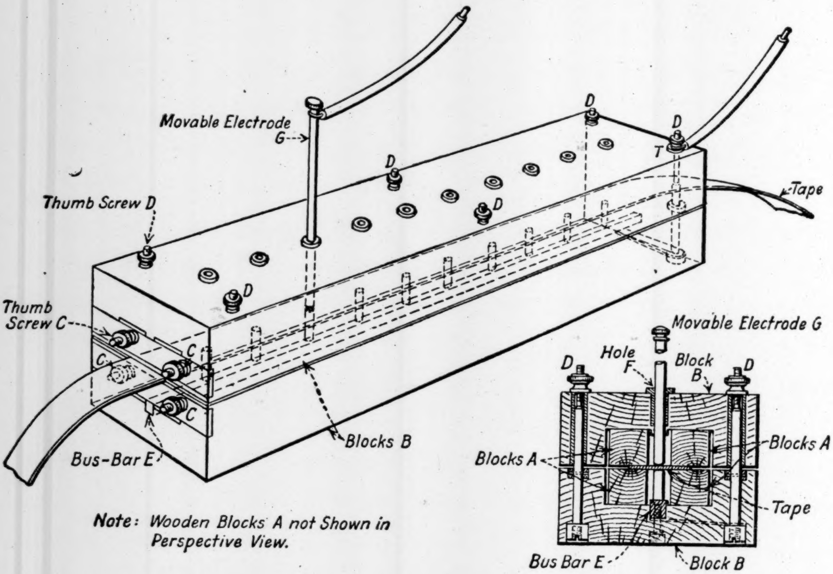
(*1*) Duration of test;
(*2*) Breakdown voltage;
(*3*) Temperature of specimen at breakdown;
(*4*) Rate of temperature rise during test.

(*b*) The report shall also include a description of the specimen and its preparation, the thickness of the insulation and the number of layers of insulation.

APPENDIX

Figure 1 shows the multiple electrode form of tape tester. In this type, a strip of tape is held between four impregnated wooden blocks, *A*, which are in turn held in place in the two main blocks, *B*, by means of the thumb screws *C* in the ends of the blocks *A*. The blocks *A* are wound butt jointed with 1-in. varnished cloth tape. The whole device is clamped tightly together by the six thumb screws *D*.

There are ten lower electrodes which are fixed to a common bus-bar *E*. The upper electrode, *G*, is movable and may be inserted into any of the bushed holes *F* which serve to align the upper electrode with the corresponding lower electrode. Voltage is applied between the upper and lower electrodes by direct connection to the upper electrode and by connection to the common bus-bar *E* through the thumb-screw terminal *D* marked *T*. The electrodes are cylindrical brass rods $\frac{1}{4}$ in. (6.35 mm.) in diameter with edges rounded to a radius of $\frac{1}{32}$ in. (0.8 mm.). The weight of the upper electrode is 0.1 lb. (45.4 g.).

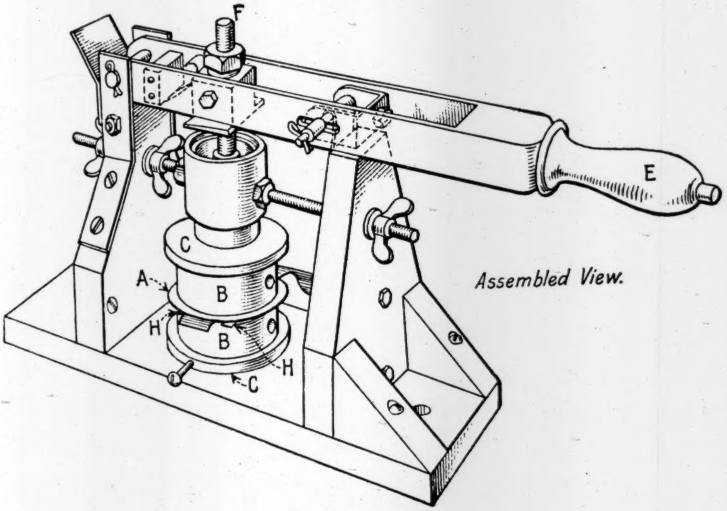


Note: Wooden Blocks A not Shown in Perspective View.

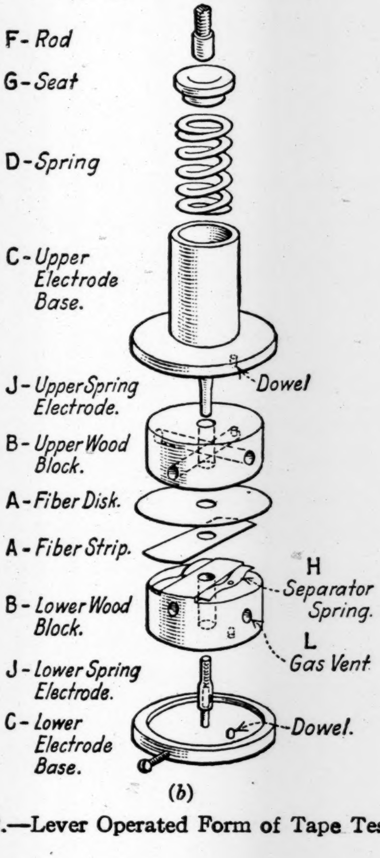
FIG. 1.—Apparatus for Dielectric Strength Test on Tape.

After the tape is secured in position, the test is made by moving the upper electrode successively from hole to hole until ten punctures have been obtained.

As more or less carbon is formed during tests, the successful operation of this device depends upon keeping the parts clean. The electrodes should be cleaned with very fine emery paper, being careful not to change their form. The blocks *A* should be rewound from time to time with new varnished cloth tape.


F
E
C
A
B
H
B
H
C
Assembled View.

(*a*) Assembled View.


F - Rod
G - Seat
D - Spring
C - Upper Electrode Base.
Dowel
J - Upper Spring Electrode.
B - Upper Wood Block.
A - Fiber Disk.
A - Fiber Strip.
H Separator Spring.
B - Lower Wood Block.
L Gas Vent
J - Lower Spring Electrode.
Dowel.
C - Lower Electrode Base.

(*b*)

Fig. 2.—Lever Operated Form of Tape Tester.

Referring to Fig. 2 (*a*), the tape is held between two pieces of fiber, *A*, which, in turn, are held between two impregnated wood blocks, *B*, held in brass bases, *C*. The blocks are pressed together by a spring, *D*, which is compressed by the latch handle, *E*, through a rounded pin, *F*, fitting into a cup-shaped cap, *G*. When the handle is released, the blocks are spread apart by two light springs, *H*, mounted on the face of the lower block. The electrodes, *J*, consist of hollow rods, fitted with very light internal springs, *K*, which hold the ends against the tape during the test. Vents, *L*, relieve any gas pressure which may develop when puncture occurs.

After considerable use, a leakage path will develop along the surface of one of the blocks and re-surfacing becomes necessary. This condition is avoided by using fiber disks as indicated in Fig. 2 (*b*). These disks are easily removed and replaced as necessary.

TENTATIVE METHODS OF TESTING UNTREATED INSULATING PAPER[1]

A.S.T.M. Designation: D 202 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1924; REVISED, 1925, 1926, 1927, 1928, 1929, 1930.

Scope.

1. These methods apply to untreated paper which is to be used as an electrical insulator or as a constituent of a composite material used for electrical insulating purposes.

SAMPLING

Sampling.

2. (*a*) From shipments consisting of rolls, a sample of at least 1 sq. yd. in area, cut across the entire width of the roll, shall be taken from every tenth roll in the shipment. From other shipments such as sheets or pads of tape, samples of equivalent area shall be taken in such a manner as to be equally representative of the shipment. In no case shall less than three samples be taken.

NOTE.—It is recommended that several turns of paper from each roll sampled be torn off and discarded before the samples are taken.

(*b*) The tests for physical properties shall be made upon each sample.

(*c*) The tests for acidity, moisture content, size,[2] ash and for identification of fibers[2] shall be made in duplicate upon portions taken from a composite sample. This composite sample shall be made up of a sufficient number of small pieces, each of approximately 6.5 sq.cm. (1 sq. in.) in area taken in nearly equal amounts from each of the samples taken in accordance with Paragraph (*a*).

(*d*) The required number of samples shall be taken at equal intervals across the sheet, the two end samples being taken at the edges of the sheet after removing any damaged paper. When it is not possible to secure the required number of specimens in this manner in going once across the sheet, the selection across the sheet shall be repeated as many times as necessary until the required number of specimens is secured.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electric Co., Schenectady, N. Y.

[2] The tests for size, identification of fibers, and folding endurance do not appear in these methods but will be included as soon as the tests are developed by the committee.

CONDITIONING SAMPLES

Conditioning. 3. Samples shall be conditioned in air maintained at a relative humidity between 60 and 65 per cent as measured with a sling psychrometer or its equivalent. The temperature of the air shall be maintained as constant as possible at some temperature between the limits of 20 and 30° C. (68 and 86° F.). The samples should remain in the conditioned air for not less than 4 hours prior to the tests and should be supported so as to allow a free circulation around each sample. The following physical tests shall be made in the conditioned air: tensile breaking strength, tearing strength, bursting strength, folding endurance,[1] air resistance, dielectric strength and thickness.

MOISTURE CONTENT

Apparatus. 4. A weighing bottle, evaporating dish, thermometer, constant-temperature oven, chemical balance and desiccator are necessary for the test. The weighing bottle should be of convenient size, about 65 mm. (2.56 in.) in height and 45 mm. (1.77 in.) in diameter with a wide mouth provided with a ground-glass stopper. The chemical balance should be sensitive to 0.1 mg.

Specimen. 5. The moisture content figure is used to calculate the percentage of acidity, size, and ash of the paper to the bone-dry basis. It shall be determined on 2 to 5-g. samples selected in accordance with Section 2 (*c*).

If the moisture content of the paper as received at the purchaser's works is desired or at any other stated time, it shall be made on the sample taken at the definitely stated time by cutting small pieces of approximately 6.5 sq. cm. (1 sq. in.) in area from the required number of rolls or pads of tape in accordance with Section 2 (*a*) and immediately placed into an air-tight container.

NOTE.—Since paper adjusts itself, as regards moisture content, to the humidity of the surrounding atmosphere in a very short time (2 or 3 minutes), special care must be exercised to transfer rapidly the sample from the roll or bundle to the container and from the container to the weighing bottle.

Procedure. 6. The sample before drying shall be weighed in the tared bottle with the stopper in place. The bottle shall then be placed in the oven at 100 to 105° C. (212 to 221° F.), the stopper removed and laid alongside of the bottle and the contents transferred to the drying dish. After one hour, while still in the oven, the sample shall be replaced in the weighing bottle, and the bottle stoppered and transferred to the desiccator. The stopper should be removed while the bottle cools. When the specimen and the bottle have cooled to room temperature, the stopper shall be replaced and the bottle with its contents weighed. This process shall be repeated at intervals of one hour until the difference in weight between two successive weighings is not more than 0.2 per cent of the weight of the specimen.

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[1] The tests for size, identification of fibers, and folding endurance do not appear in these methods but will be included as soon as the tests are developed by the committee.

NOTE.—The weighing bottle or sample should not be touched with the fingers during this test.

7. The moisture content shall be expressed: **Report.**

(*a*) as a percentage of the weight of the dry sample, and

(*b*) as a percentage of the weight of the undried sample.

THICKNESS

8. A micrometer of the spring actuated, dial type shall be used. **Apparatus.** The plunger shall be capable of being raised by the application of an upward pressure to it. The plunger surface shall be circular in shape and 12.7 mm. (0.50 in.) in diameter. The anvil surface shall be plane and circular in shape, the diameter of which shall be not less than 12.7 mm. (0.50 in.). It shall be centered with respect to the plunger surface.

In addition to these requirements, the instrument shall conform to the following:

(*a*) The pressure applied to the plunger necessary to move the pointer from zero toward a positive reading shall not be greater than 1135 g. (40 oz.).

(*b*) The pressure applied to the plunger necessary to just prevent movement of the pointer from zero toward a lower reading shall not be less than 455 g. (16 oz.).

(*c*) The diameter of the dial shall be approximately 15 cm. (6 in.) and shall be graduated preferably in divisions indicating a thickness of 0.0127 mm. (0.0005 in.) and in no case greater than 0.0254 mm. (0.001 in.). Graduations indicating a thickness of 0.0254 mm. (0.001 in.) shall be at least 3 mm. (0.12 in.) apart.

(*d*) Measurements made on standard steel thickness gages shall be within the following tolerances:

INTERVALS	PERMISSIBLE DEVIATION OF READING FROM ACTUAL THICKNESS OF STANDARD STEEL GAGE
0 to 0.25 mm. (0 to 0.01 in.) incl.	±0.0025 mm. (0.0001 in.)
Over 0.25 mm. to 1.02 mm. (0.01 in. to 0.04 in.) incl.	±0.0051 mm. (0.0002 in.)
Over 1.02 mm. to 3.05 mm. (0.04 in. to 0.12 in.) incl.	±0.0102 mm. (0.0004 in.)

(*e*) Convenient means shall be provided for setting the pointer to the zero position.

(*f*) The micrometer shall be tested periodically as outlined above and if it does not conform to these requirements its mechanism should be readjusted.

NOTE.—Work is now under way in Committee D-9 toward standardizing the use of the 1-in. machinist's type micrometer.

Specimens. 9. Specimens shall consist of the original samples obtained in accordance with Section 2 (*a*).

Methods. 10. At least five readings shall be taken at regular intervals across the entire width of each specimen. When measuring paper less than 0.05 mm. (0.002 in.) in thickness, a sufficient number of layers to give a reading on the scale of not less than 0.13 mm. (0.005 in.) shall be used.

In making measurements the plunger shall be raised to a point where its lower surface is from 0.45 to 0.55 mm. above the surface of the paper specimen lying in contact with the surface of the fixed anvil. The plunger shall be dropped from this height on the paper without retarding its speed of descent. When the thickness is read, care shall be taken not to touch the instrument.

Report. 11. The average, maximum and minimum thicknesses obtained on each specimen shall be reported.

TENSILE BREAKING STRENGTH

Apparatus. 12. (*a*) A testing machine of the dead-weight pendulum type suitably designed for testing paper shall be used. The machine shall preferably be power driven.

(*b*) The capacity of the machine shall not exceed 113 kg. (250 lb.).

(*c*) The machine shall be graduated to read 1 lb. or 1 kg. or less per scale division for testing paper breaking at 22.7 kg. (50 lb.) or over, and to 0.5 lb. or 0.5 kg. or less for testing paper breaking under 22.7 kg. (50 lb.).

Specimens. 13. From each of the samples selected in accordance with Section 2 (*a*), specimens shall be cut at least ten in the machine direction and if practicable, ten in the cross-machine direction. The specimens shall not exceed 2.54 cm. (1 in.) in width and shall be 25.4 cm. (10 in.) in length with clean-cut edges.

Procedure. 14. (*a*) The ratio of the clearance distance between jaws to the width of the specimen shall not be less than 5 to 1 nor more than 10 to 1.

(*b*) The rate of travel of the movable jaw shall be constant. It shall preferably be 30.5 cm. (12 in.) per minute, but it may be within the limits of 28 cm. (11 in.) and 33 cm. (13 in.) per minute provided it is constant.

(*c*) All readings obtained when the paper breaks at or in the jaws shall be rejected.

15. (*a*) The results of the machine-direction specimens and the cross-machine-direction specimens shall be reported separately. **Report.**

(*b*) The results shall be reported in kilograms or pounds together with the width of the specimen in centimeters or inches and also the average thickness.

(*c*) The maximum, minimum, and average breaking load shall be reported for the machine direction and the cross-machine direction.

TEARING STRENGTH

16. The testing machine shall be of the pendulum impulse type so designed as to produce a tear approximately 4.2 cm. (1.66 in.) long. The knife mounted on the machine to cut the slit for the tear shall be maintained sharp. **Apparatus.**

17. The specimens shall be taken from the original samples obtained in accordance with Section 2 (*a*) and shall be cut 6.3 cm. (2.5 in.) in width and at least 6.3 cm. (2.5 in.) in length. Enough specimens shall be cut so that at least five readings in the machine direction and five readings in the cross-direction, if possible, can be obtained for each original sample. **Specimen.**

18. Enough paper shall be torn so that the readings on the machine shall be not less than 10 nor more than 20 g., unless one paper alone yields a reading greater than 20 g., in which case only one paper shall be torn at one time. The specimens shall be so arranged that an equal number of tears originating from opposite edges of the specimens will be produced. Readings obtained when a tear deviates more than 6.3 mm. (0.25 in.) from a straight line, shall be rejected. The readings obtained shall be multiplied by the instrument constant corresponding to the number of sheets torn. **Method.**

19. (*a*) The tearing strengths obtained on the machine-direction specimens and on the cross-direction specimens shall be reported separately in grams. **Report.**

(*b*) The average, the maximum, and the minimum tearing strengths shall be reported for the machine-direction specimens. If possible, similar results shall be reported for the cross-direction specimens.

BURSTING STRENGTH

20. The testing machine shall have a circular flexible diaphragm 6.44 sq. cm. (1 sq. in.) in area. The pressure chamber shall be filled with glycerin or other suitable pressure medium and shall contain no air spaces. The test specimen shall be held in position over the diaphragm in a clamp having a circular hole approximately 6.44 sq. cm. (1 sq. in.) in area so that the diaphragm will force the paper into the hole when pressure is applied under the diaphragm. The pressure exerted on the diaphragm shall be indicated on a dial, graduated to **Apparatus.**

at least 0.23 kg. (0.5 lb.) for papers giving bursting strengths 18 kg. (40 lb.) or under. A dial graduated 0.45 kg. (1 lb.) may be used in testing papers which give higher bursting strengths. The machine may be either hand-operated or power-driven, the latter being preferable.

Specimen. 21. If practicable, the specimen shall be so cut from the stock as to permit ten bursting tests on a line across the sheet or roll.

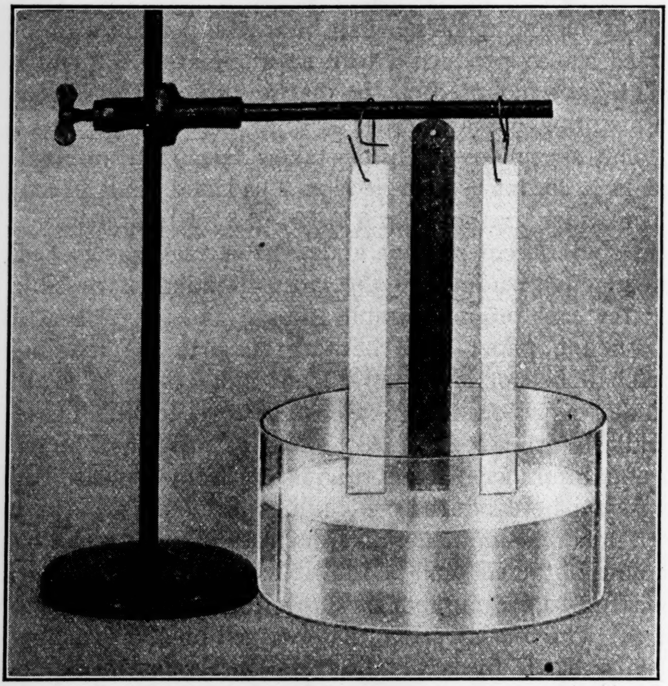

FIG. 1.—Apparatus for Absorption Test.

Procedure. 22. Ten bursts shall be made, five with one side of the paper uppermost and five with the other side uppermost. The testing machine shall be driven at a uniform speed of 120 r.p.m. until the specimen bursts.

Report. 23. The report shall include the average, the maximum, and the minimum results obtained.

ABSORPTION

(RISE OF WATER)

Apparatus. 24. A suitable container and support for specimens and scale is shown in Fig. 1.

25. Ten strips 2.5 cm. (1 in.) in width and at least 12.5 cm. (5 in.) in length shall be cut from the samples obtained in accordance with Section 2 (*a*), five being cut parallel with the machine direction of the paper and five being cut parallel with the cross-direction of the paper. **Specimens.**

26. The specimens shall be suspended vertically with one end dipping 3.2 mm. (0.125 in.) in distilled water at room temperature. **Procedure.**

After five minutes of suspension, the rise of the water in the paper above the water level shall be noted. The rise may be measured by reading directly from the scale the height of absorption.

27. The rise of water shall be reported in millimeters to the nearest 3 mm. or in inches to the nearest $\frac{1}{8}$ in. **Report.**

MIL WEIGHT PER REAM

(APPARENT DENSITY)

28. A scale, sharp knife, chemical balance and weighing bottle are necessary for the test. **Apparatus.**

29. Duplicate specimens shall be taken from as widely separated portions as possible from each of the samples obtained in accordance with Section 2 (*a*) and conditioned in accordance with Section 3. **Specimens.**

30. (*a*) Each specimen while in the conditioned atmosphere (see Section 3) shall be cut accurately to any convenient size, for example, 232.3 sq. cm. (36 sq. in.) in area, and accurately weighed. Specimens of sufficient size to weigh at least from 3 to 5 g. (0.11 to 0.18 oz.) should be taken. If it is not possible to do the weighing in the conditioned atmosphere, the specimen shall be placed in a weighing bottle and tightly stoppered with a ground glass stopper before being removed from the conditioned atmosphere. The thickness of each specimen shall be determined in accordance with Section 10. **Procedure.**

(*b*) *Mil Weight per Ream of Any Size.*—The mil (or point) weight in pounds per ream of any size may be calculated from the following formula:

$$W = 0.002205 \frac{mSN}{ta}$$

where m = the weight of the specimen expressed in grams;

t = the average thickness of the specimen expressed in mils (thousandths of an inch);

a = the area of the specimen expressed in square inches;

S = the area of one sheet in the basic ream expressed in square inches;

N = the number of sheets in the ream.

NOTE.—0.002205 is contracted from 0.00220462.

NOTE.—The following formulas may be used to calculate the mil weight in pounds per ream for reams of particular sizes, provided a specimen of exactly 232.3 sq. cm. (36 sq. in.) is used:

Ream of 24 by 36 in., 480 sheets.

$$W = 25.40 \frac{m}{t}$$

where m = the weight of specimen expressed in grams;
t = the average thickness of the specimen in mils (thousandths of an inch)
25.40 is contracted from 25.3972224.

Ream of 24 by 36 in., 500 sheets.

$$W = 26.45 \frac{m}{t}$$

where m and t are the same as above and 26.45 is contracted from 26.45544.

NOTE.—The ream weight may be obtained from the above formulas by omitting the thickness "t".

(*c*) *Weight per Unit Volume.*—The weight in pounds per cubic foot (density) may be calculated from the following formula:

$$D = 3810 \frac{m}{ta}$$

where m = the weight of the specimen expressed in grams.
t = the average thickness of the specimen expressed in mils (thousandths of an inch).
a = the area of the specimen expressed in square inches.

NOTE.—3810 is contracted from 3809.58336.

NOTE.—To convert weight in pounds per cubic foot to mil weight in pounds per ream of 24 by 36 in., 480 sheets, multiply by 0.24; to convert to mil weight in pounds per ream of 24 by 36 in., 500 sheets, multiply by 0.25.

Report. 31. The weight in pounds per cubic foot or the mil weight per ream shall be reported. The size of the ream must be given when the mil weight per ream is reported.

AIR RESISTANCE

Apparatus. 32. (*a*) The instrument shall consist of two aluminum open-top cylinders, one of which is inverted and slides into the other which is fixed. The movable cylinder shall be provided with a circular aperture in the closed end and a flat ring clamp for holding the paper specimen across this aperture.

(*b*) The fixed cylinder shall be 25.4 cm. (10 in.) in height and shall have an external diameter of 8.60 cm. (3.38 in.) and an internal diameter of 8.25 cm. (3.25 in.). Four slender bars, each 18.5 cm. (7.3 in.) long, 3 mm. (0.12 in.) wide and approximately 1.5 mm. (0.06 in.) thick shall be mounted vertically and equi-distantly on the inner surface of the fixed cylinder to act as guide tracks for the movable cylinder. The movable cylinder shall be graduated in units of 50 cc. and shall have a total range of 350 cc. It shall be 25.4 cm. (10 in.)

high and shall have an external diameter of 7.62 cm. (3.00 in.) and an internal diameter of 7.35 cm. (2.90 in.). It shall weigh, including the flat ring clamp and the two knurled nuts, 567 g. ± 0.5 g. (20 oz. ± 0.018 oz.). The movable cylinder and the flat ring clamp shall have a concentric circular aperture of 6.44 sq. cm. (1.00 sq. in.) in area. When this aperture is too large for the specimen a similar movable cylinder and flat ring clamp having a concentric circular aperture of 1.61 sq. cm. (0.25 sq. in.) in area shall be used.

NOTE.—Results obtained with apertures of different areas are not directly proportional to the areas of the apertures. The proportionality factor must be determined by experiment.

Specimen. 33. The specimens shall be not less than 3.5 cm. (1.36 in.) nor more than 5.1 cm. (2.0 in.) in width cut from the original samples, taken in accordance with Section 2 (*a*) and shall be as long as the width of the original roll of paper. If the specimens are selected from pads of tape they shall be not less than 2.1 cm. (0.81 in.) nor more than 5.1 cm. (2.0 in.) wide and at least 30 cm. (12 in.) long. There shall be as many specimens as there are original samples.

Procedure. 34. The fixed cylinder shall be placed on a rigid support so that its sides are vertical. A lubricating oil with viscosity of 60 to 70 seconds Saybolt at 37.8° C. (100° F.) shall be placed in it to a depth of 12.7 cm. (5 in.). The specimen (one thickness only) shall be secured tightly under the clamp on the movable cylinder completely covering the aperture. The movable cylinder is then floated on the lubricating oil. The time required for the displacement of a certain amount of air shall be noted with a stop-watch. If possible, the amount of air displaced should be such that the time of displacement is not less than 20 seconds. The apparatus with its content of lubricating oil shall be at the temperature of the conditioning room when the readings are taken. The time in seconds required for the displacement of 100 cc. (6.1 cu. in.) of air through a circular area (one side only) of 6.44 sq. cm. (1 sq. in.) of the paper is known as the air resistance of the paper.

NOTE.—The clamp shall be tested for leakage by substituting a piece of tinfoil 0.05 mm. (0.002 in.) in thickness for the paper and testing in the manner described above. When so tested, the leakage shall not exceed the rate of 50 cc. in five hours.

The proper procedure for clamping the specimen or tinfoil is to turn both knurled nuts down onto the clamp simultaneously. If only one nut at a time is turned down, the clamp will not fit flat on the specimen and will consequently have an avoidable leak.

Oil is used in preference to distilled water because it does not corrode aluminum whereas distilled water does.

Precautions should be taken to avoid subjecting the apparatus to vibration as this condition would increase the rate of air displacement.

Report. 35. The report shall include the following:

(*a*) the number of seconds required for the displacement of 100 cc. (6.1 cu. in.) of air;

(*b*) the area of paper through which the air was displaced;

(*c*) the thickness of the paper as obtained under Section 11; and

(*d*) the room temperature.

NOTE.—The following values show the probable accuracy obtainable in the air-resistance tests:

AIR RESISTANCE	ACCURACY
40 seconds	± 5 per cent
100 seconds	± 6 per cent
200 seconds	± 8 per cent
300 seconds	± 10 per cent

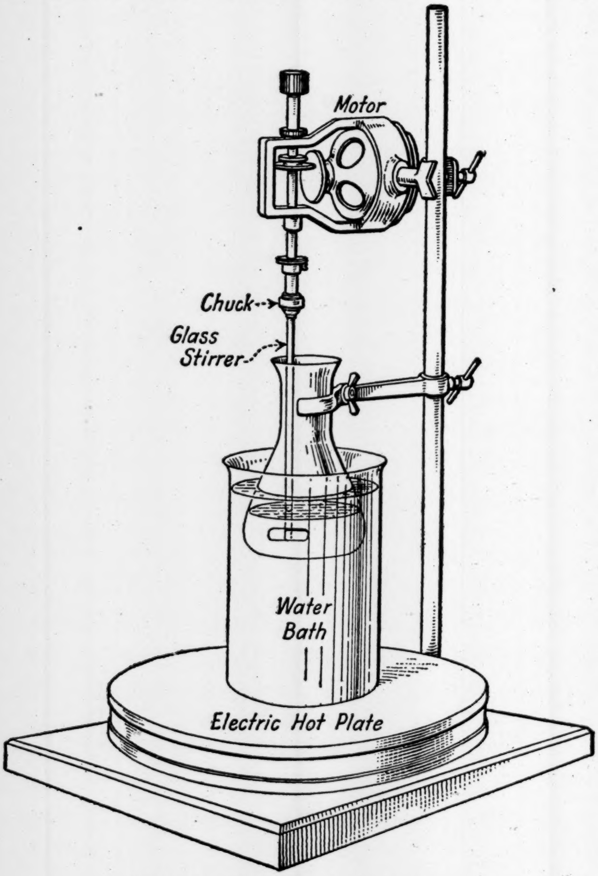

FIG. 2.—Extraction Apparatus.

ASH

Apparatus. 36. A suitable crucible such as platinum, nickel or porcelain, a balance sensitive to 0.1 mg., and a desiccator are necessary for the test.

37. Not less than 2 g. of dry, finely-divided paper from the "moisture determination" sample as obtained in accordance with Section 6 shall be used. **Specimen.**

38. The sample shall be transferred rapidly from the weighing bottle containing the dried sample into the crucible. The weighing bottle shall immediately be re-stoppered and re-weighed, and the exact weight of the sample obtained by taking the difference in weights of the weighing bottle and the sample. The sample shall be completely ignited in the crucible, preferably in a muffle furnace, all precautions being taken to prevent loss of ash or sample. The residue of incombustible mineral matter (ash) shall be desiccated, cooled and weighed, and the amount computed as a percentage of the weight of the dried sample. **Procedure.**

39. The amount of ash shall be reported as a percentage of the weight of the dry sample (see Section 7 (*a*)) and also as a percentage of the weight of the undried sample (see Section 7 (*b*)). **Report.**

ACIDITY OR ALKALINITY

40. (*a*) A hot water bath, electric hot plate, motor with stirrer, 50-cc. glass burette graduated to 0.1 cc., 250-cc. wide-mouth Erlenmeyer flasks, thermometer graduated to 1° C., covering the range from 50 to 100° C., and a filtering apparatus, are required for the test. **Apparatus.**

(*b*) The Erlenmeyer flasks and the stirrer shall be of acid-resistant and alkali-resistant glass. The stirrer shall consist of a glass shaft, one end of which shall be fitted to a chuck attached to the motor shaft (see Fig. 2). The other end of the stirrer shall be fashioned into a two-bladed propeller, each blade to be approximately 15 mm. (0.59 in.) long and 6 mm. (0.24 in.) wide. The pitch of the blades and the direction of rotation shall be such as to produce a downward current along the glass shaft when the stirrer is rotated in the liquid, thus preventing spattering.

(*c*) The following reagents shall be required: Solutions of sodium hydroxide (NaOH) and sulfuric acid (H_2SO_4) in water, each being 0.01 *N* in strength; solution of 0.5 g. of phenolphthalein dissolved in 100 cc. of c. p. ethyl alcohol.

41. From the original samples obtained in accordance with Section 2 (*a*), a composite sample of at least 5 g. (0.175 oz.) shall be cut into small pieces, approximately 1 cm. (0.4 in.) square. The sample shall be thoroughly mixed, and during preparation contamination by handling shall be avoided. **Sample.**

42. (*a*) *Extraction.*—One gram of the composite sample shall be placed in a 250-cc. Erlenmeyer flask and 100 cc. of boiling, distilled **Procedure.**

water added. The flask shall then be clamped in position in a water bath[1] heated to 100° C. on a hot plate. The level of the water in the bath shall be slightly above the level of that in the flask, and the temperature of the contents of the flask shall remain at least as high as 95° C. during the stirring operation. The stirrer shall be mounted so that the blades are within 3 mm. (0.12 in.) of the bottom of the flask and offset from the center in order to obtain best beating action. The stirrer shall be driven at a speed of 4000 to 5000 r.p.m. for 5 minutes. At the end of this period the sample should have been thoroughly pulped. For papers unusually difficult to pulp, the period of stirring shall be increased to 10 minutes.[2]

NOTE.—It has been definitely determined that 3000 r.p.m. is too low to pulp the sample effectively within 5 minutes.

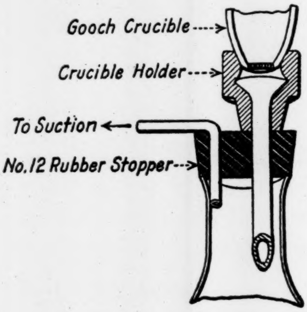

FIG. 3.—Filtration Apparatus.

(*b*) *Titration.*—Immediately after the sample has been pulped, the contents of the flask shall be filtered rapidly into another 250-cc. Erlenmeyer flask without washing.

NOTE.—It is important that the filtration of the extract be accomplished as promptly as possible after disintegration to prevent re-absorption of acidic or alkaline material from the extract by the pulp as the temperature falls. A convenient method consists of a 25-cc. porcelain Gooch crucible and holder assembly, like that shown in Fig. 3. The pulp forms a filter mat of itself over the perforations in the bottom of the crucible and the first portion of the filtrate is re-filtered to catch the fibers which go through during the formation of the mat.

The filtered extract shall be boiled for 3 minutes and immediately titrated before the temperature falls below 80° C., thus eliminating the error due to dissolved carbon dioxide.

If the extract is acidic, it is titrated with $0.01N$ NaOH, using 5 drops of the specified phenolphthalein solution as indicator. The end-point is determined by the appearance of a definite pink color. If the extract is alkaline, a small excess of 0.01*N* H_2SO_4 is added and the titration then completed with 0.01*N* NaOH as described above.

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[1] At high altitudes a salt bath will be necessary to obtain the temperature required.

[2] Any other method of pulping the sample as rapidly and thoroughly, while maintaining a temperature of 95° C. within the flask during extraction, should prove satisfactory.

NOTE.—To find the proper color transformation at the end-point, a blank titration should be made on boiling distilled water under the above specified conditions. The result should check with the curve shown in Fig. 4. This curve will be found valuable as a check on the purity of the distilled water used, although its chief purpose is to indicate the proper blank correction to be applied to the titration.

The number of cubic centimeters of titer solution shall be recorded, together with the temperature and volume of the solution taken

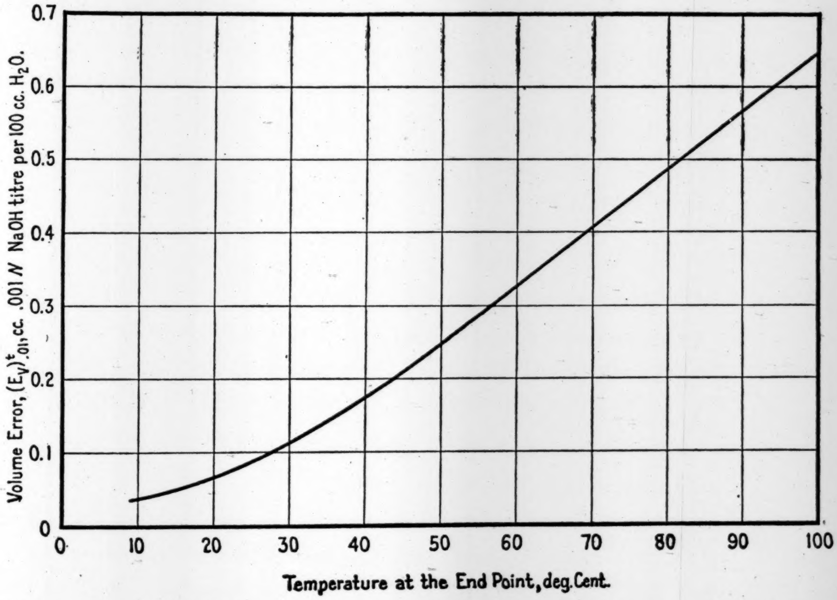

FIG. 4.—Showing Titration Error Due to Volume and Temperature of Water in a Solution at its End-Point.

If $(E_v)\frac{t}{N}$ represents the volume error of a solution where *t* and *V* are the temperature and volume at the end-point of a titration, and $N =$ the normality of the titer, then it is calculated as follows:

$$(E_v)\frac{t}{N} = (E_v)^t 0.01 \times \frac{0.01}{N} \times \frac{V}{100}$$

immediately upon the completion of the titration, as these figures enter into the blank correction for the volume error (E_v).

43. (*a*) *Blank Correction.*—The correction for the blank error in the titration shall be made in either of two ways: **Report.**

(*1*) By running a blank in parallel with the actual determination using a volume of pure distilled water equal to that of the extract at the end-point;

(*2*) By calculating the blank error with the aid of the curve shown in Fig. 4.

NOTE.—The second method is the more convenient and probably more reliable. This curve shows the number of cubic centimeters of $0.01N$ NaOH solution required to produce an end-point at various temperatures in 100 cc. of distilled water, using 5 drops of the specified indicator. Correction by the use of this curve is valid only if the solution has been boiled and titrated at elevated temperatures to insure absence of dissolved CO_2.

This correction is the number of cubic centimeters of titer solution (volume error) corresponding to the point on the curve determined by the temperature and volume of the solution at the end-point. If the solution is acidic, this blank correction shall be subtracted from the volume of titer used; if alkaline the correction shall be added.

(*b*) *Calculation.*—The acidity or alkalinity shall be calculated from the following equation:

$$\text{Percentage acidity (or alkalinity)} = \left\{\begin{array}{c}\text{cubic centimeter titer}\\ \text{solution (corrected)}\end{array}\right\} \times \frac{\text{normality}}{1000} \times 40 \times 100$$

A simpler form is:

$$\text{Percentage acidity (or alkalinity)} = \left\{\begin{array}{c}\text{cubic centimeter}\\ \text{titer (corrected)}\end{array}\right\} \times \text{normality} \times 4.$$

(*c*) *Expression of Results.*—The results shall be expressed as the equivalent weight per cent of NaOH if the extract is acidic, or as equivalent weight per cent of SO_3 if the extract is alkaline; this percentage being based on the weight of the air-dry sample in grams.

NOTE.—SO_3 is used rather than H_2SO_4 in this calculation as the equivalent weight of SO_3 is identical with that of NaOH, and this makes it possible to express acidity or alkalinity in directly comparable terms.

(*d*) *Number of Tests.*—At least two samples shall be carried through the foregoing procedure. If in duplicate samples the values of percentage acidity or alkalinity do not agree within 0.005, the determinations shall be repeated.

NOTE.—There is given in an appendix to the report of Committee D-9 for 1926,[1] information regarding the details of the foregoing method, and reasons are presented for the selection of the conditions specified.

SURVEY FOR CONDUCTING PATHS

Scope. 44. The survey for conducting paths in untreated insulating paper is a test to determine the number of conducting paths in the paper as indicated by the number of electrical breakdowns (or points of excessive current flow in thin papers (see Section 45 (*b*)) when relatively large areas of the paper are subjected to a voltage somewhat lower in value than the dielectric strength of the paper when tested in accordance with Sections 2 to 12 of the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 461 (1926).

(A.S.T.M. Designation: D 149 - 30 T) of the American Society for Testing Materials.[1]

Apparatus.

45. (*a*) The survey shall be made by passing a specimen of the paper between metallic electrodes across which a voltage is impressed. The arrangement of the apparatus may be of any convenient form which will allow the application of the required voltage to a specimen of relatively large area, and will allow the electrical breakdowns to be indicated so that the number of these may be counted.

(*b*) For papers having a thickness of 0.038 mm. (0.0015 in.) or less it has been found preferable to use a detecting device such as a telephone receiver to detect the excessive current through the conducting paths rather than to allow complete electrical breakdown of the specimen. Also, it is preferable to pass one electrode over the paper rather than to draw the paper through between the electrodes.

Specimens.

46. The specimen shall be of relatively large area, such as a pad of tape, or a sheet from each sample of paper (see Section 2 (*a*)).

Procedure.

47. The survey shall be made by passing the specimen between the metallic electrodes at a speed of 30 to 60 ft. per minute. The voltage impressed across the electrodes shall be 100 volts per mil thickness of the specimen if alternating voltage is used, or 141 volts per mil thickness of the specimen if direct voltage is used.

NOTE 1.—If the voltage values specified above prove inconvenient of application, a lower voltage may be used, in which case it is necessary to establish a relationship between the conducting paths at this voltage and at the specified voltage. A lower value of conducting paths will be obtained at the lower voltage.

NOTE 2.—A description of equipment and a procedure which have been found suitable for making this survey of conducting paths in different thicknesses of paper appears in the Appendix.

Report.

48. The report shall include the following:

(*a*) The total number of conducting paths and the conducting paths per unit area.
(*b*) The length, width, area, and thickness of the specimen.
(*c*) The voltage applied expressed in volts, and volts per mil thickness of specimen.
(*d*) The speed of the paper.

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[1] See p. 1188.

APPENDIX

DESCRIPTION OF APPARATUS FOR A SURVEY FOR CONDUCTING PATHS IN UNTREATED INSULATING PAPERS

Equipment and procedure which have been found to be suitable for making the survey of conducting paths for different thicknesses of paper are as follows:

For Paper Having a Thickness of 0.038 mm. (0.0015 in.) or Under.—For paper having a thickness of 0.038 mm. (0.0015 in.) or under, a brass plate, a brass roller with an insulated handle, a pair of telephone receivers having a total resistance of 3000 ohms, a resistor of 80,000 ohms, and a source of direct voltage of 110 volts is used in this test. The brass plate is 31.8 cm. (12.5 in.) in width and 38.7 cm. (15.25 in.) in length and is machined and polished until its surface is level and smooth. The brass roller has a diameter of 5.08 cm. (2 in.) and a face of 2.54 cm. (1.00 in.) in width. The surface of the roller should be accurately cylindrical and polished so that it will always make a line contact when it is rolled over the brass plate in any direction. A brass plate which will warp the least is best obtained by casting a plate at least 2.54 cm. (1.00 in.) in thickness and dressing down the surface to the desired smoothness.

The size of the specimen is 38.7 cm. (15.25 in.) square, and is prepared for test as follows: Using a soft pencil (No. 2) and bearing lightly, mark off 12 swaths on each specimen (see Fig. 1). Each swath is 2.54 cm. (1 in.) in width and 30 cm. (12 in.) in length. The swaths are spaced 0.63 cm. (0.25 in.) from each other. The specimen is then placed on the brass plate in such a manner that the ends of all the swaths are spaced 0.63 cm. (0.25 in.) from the edges of the brass plate. The specimen may be held in position by means of two weights as shown in Fig. 1.

Connect the brass roller to one pole of the 110-volt circuit. Connect the brass plate, the 80,000-ohm resistance and the telephone receivers in series to the other pole of the 110-volt circuit. (See Fig. 1.) Run the brass roller once over each swath slowly in succession and count the clicks audible in the telephone receivers. Each click is considered to represent a conducting path. The total number of clicks counted on all the specimens divided by the total area of all the swaths of all the specimens, is the number of conducting paths per unit area.

For Paper Having a Thickness Greater Than 0.038 mm. (0.0015 in.) and Less Than 0.76 mm. (0.030 in.).—For paper having a thickness greater than 0.038 mm. (0.0015 in.) and less than 0.76 mm. (0.030 in.) a transformer with regulating equipment to give the required voltage, a voltmeter, a source of alternating voltage, a brass plate and a set of brass rollers are used. The brass plate is 15.2 cm. (6 in.) in width and 122 cm. (48 in.) in length and is machined and polished until its surface is level and smooth. Each brass roller has a diameter of 3.81 cm. (1.5 in.) and a face 2.54 cm. (1 in.) in width. The surface of each brass roller is accurately cylindrical and polished so that it makes a line contact when it is placed in its position on the brass plate. The brass rollers are mounted in two parallel rows above the brass plate in such a manner as to permit each individual roller to be raised away from the brass plate or lowered to make a line contact with it. The rollers in each row are spaced and have a common geometric axis. The axes of the two rows of rollers are parallel to each other and also to the long edges of the brass plate. The rollers in one row are staggered with respect to the rollers in the other row so that the surface of paper passing under the first row of rollers will be partially overlapped by the second row of rollers (see Fig. 2). The entire surface of the paper makes contact with the rollers at least once and a part of the surface of the paper will make contact twice. The rollers and plate are adequately insulated from each other.

The specimen is 7.61 meters (25 ft.) in length. Place the specimen between the brass plate and the brass rollers. During the test period the moisture content of the specimen shall not exceed 7 per cent. Lower the brass rollers to make contact with the specimen. Before connecting the transformer to the source of alternating voltage, connect the brass plate to one of the high-voltage terminals of the transformer, and the brass rollers, in multiple, to the other high-voltage terminal of the transformer. Then connect the low-voltage side of the transformer with its regulating equipment to the source of alternating voltage. Adjust the voltage between the brass plate and the brass rollers to the required value (100 volts per mil thickness of the specimen). Pass the specimen along between the rollers and the plate at a speed not to exceed 9.75 m. (32 ft.) per minute and count the number of holes burned in the specimen. Each hole shall be considered as representing a conducting path. The total number of holes counted in all the specimens divided by the total area covered (one side only) of all the specimens is the number of conducting paths per unit area.

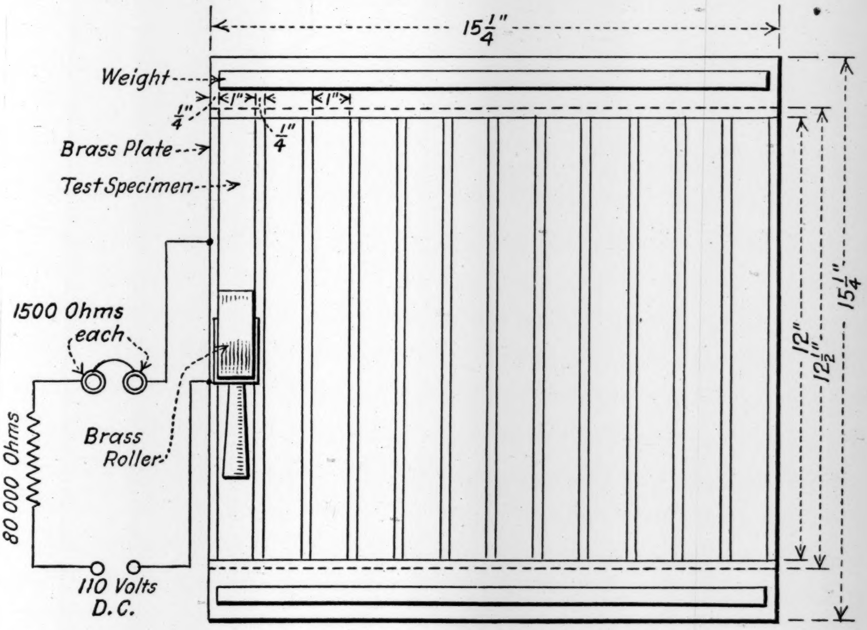


FIG. 1.—Arrangement of Apparatus for Surveying Thin Paper for Conducting Paths.

NOTE.—*Caution:* Disconnect the transformer from the source of alternating voltage before proceeding to place the next specimen between the brass plate and brass rollers.

Specimens in the form of pads of tape may be conveniently tested with an apparatus somewhat similar to the above wherein the pad is mounted on a suitable drum and the entire length of the paper in the pad rerolled on to a second drum, the paper meanwhile passing between two cylindrical rollers across which voltage is applied. The lower roller is somewhat wider than the tape and the upper roller somewhat narrower to prevent arcing through the air between the rollers. The conducting paths are counted by means of a relay and mechanical counter.

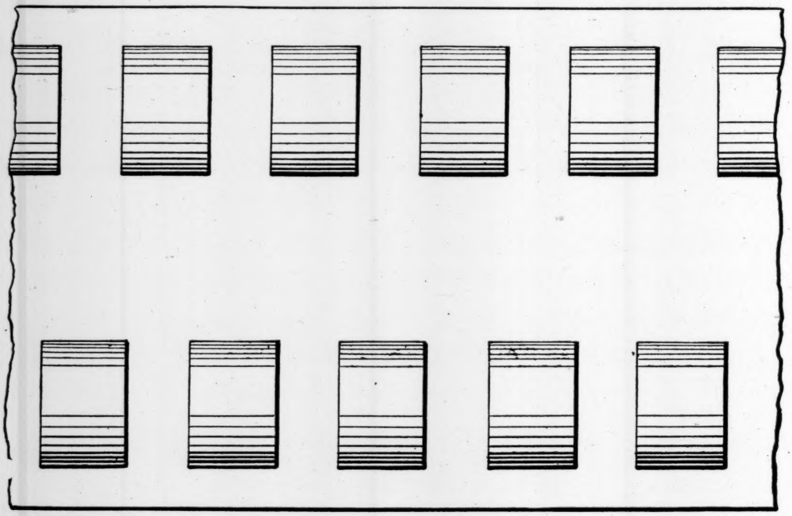
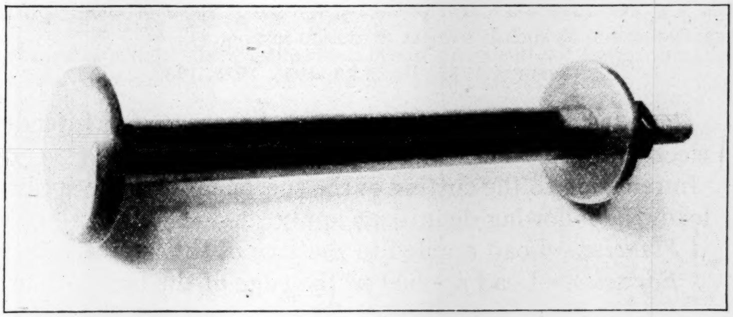
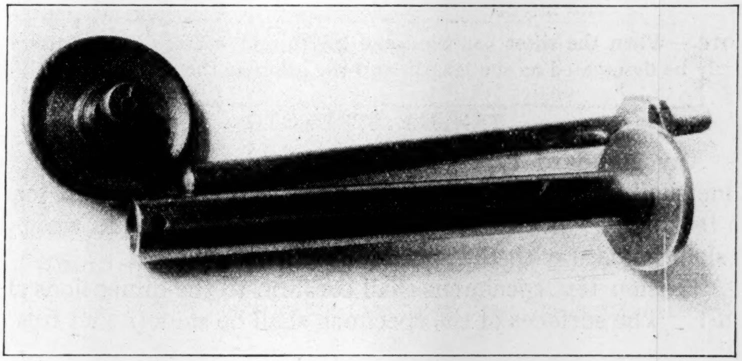


FIG. 2.—Arrangement of Brass Rollers Used in Surveying Paper for Conducting Paths.

For Paper Having a Thickness of 0.76 mm. (0.030 in.) or Over.—For paper having a thickness of 0.76 mm. (0.030 in.) or over a transformer with regulating equipment to give the required voltage, a voltmeter, a source of alternating voltage, a brass plate and a set of disc electrodes are used. The brass plate is 20.3 cm. (8 in.) in width and 122 cm. (48 in.) in length and is machined and polished until its surface is level and smooth. The contact surface of the disc electrodes has a diameter of 3.81 cm. (1.5 in.) with edges rounded to a curvature of 0.64 cm. (0.25 in.) radius. Figure 3 (*a*) shows a convenient design and Fig. 3 (*b*) shows the parts unassembled. The contact surface of each electrode is machined and polished until it is level and smooth and makes an accurate surface contact when it is placed in its position on the brass plate. The disk electrodes are mounted in four parallel rows above the brass plate in such a manner as to permit each individual electrode to be raised away from the brass plate or lowered to make an accurate surface contact with the plate. The four rows of electrodes are parallel to the long edges of the brass plate. The electrodes in one row are staggered with respect to the electrodes in each of the other rows so that the surface of a sheet of paper passing under the electrodes of the first row will be partially overlapped by the electrodes in the second row. Likewise, the surface of paper passing under the electrodes of the second row will be partially overlapped by the electrodes in the third row. And finally, the surface of paper passing under the electrodes of the first and third rows will be partially overlapped by the electrodes in the fourth row. When a sheet of paper has been passed under these four rows of electrodes, the entire surface of the paper will have made contact with the electrodes at least once and a part of the paper surface will have made contact twice. The electrodes and the brass plate should be adequately insulated from each other.



(*a*) Assembled.



(*b*) Unassembled.

FIG. 3.—Disk Electrode for Surveying Paper Over 0.76 mm. in Thickness for Conducting Paths.

The specimen is 7.61 meters (25 ft.) in length. Place the specimen between the disk electrodes and the brass plate. Lower the electrodes to make contact with the specimen, and then proceed as described above for paper 0.038 mm. (0.0015 in.) to 0.76 mm. (0.030 in.) in thickness, except that the specimen is passed between the electrodes and the brass plate at a speed not to exceed 11 m. (36 ft.) per minute. The voltage between the plate and the electrodes should be 100 volts per mil thickness of the specimen.

TENTATIVE METHODS OF TESTING LAMINATED SHEET INSULATING MATERIALS[1]

A.S.T.M. Designation: D 229 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1926, 1928, 1930.

Scope. 1. These tests apply to laminated flat sheet materials intended for use as electrical insulation.[2]

Definition of Terms. 2. In referring to the cutting of the specimens and the application of the load, the following definitions apply:

Flatwise.—Load applied to the face of the laminations.
Edgewise.—Load applied to the edge of the laminations.
Lengthwise.—In the direction of the length of the sheet.
Crosswise.—In the direction at right angles to the length of the sheet.

NOTE.—When the sheet has the same length and width, one dimension shall arbitrarily be designated as the length, and the other as the width.

TENSILE STRENGTH

Apparatus. 3. Any standard type of testing machine may be used. The machine shall be accurate to within 1 per cent on the lowest load for which it is used. Jaws which tighten under load, such as wedge grip jaws, shall be used with the specimen properly aligned.

Specimens. 4. Tension test specimens shall conform to the dimensions shown in Fig. 1. The surfaces of the specimen shall be smooth and free from scratches.

Procedure. 5. Five specimens cut lengthwise and five specimens cut crosswise of the sheet shall be tested.

Temperature. 6. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine. 7. The cross-head speed of the testing machine shall be such that the load can be accurately weighed, but shall not exceed 0.05 in. per minute when the machine is running idle.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electric Co., Schenectady, N. Y.

[2] Tests for shearing strength, compressive strength, moisture absorption, oil absorption and degree of curing are being studied by the committee. Various mechanical tests, particularly applicable to thin laminated sheet materials, are being developed.

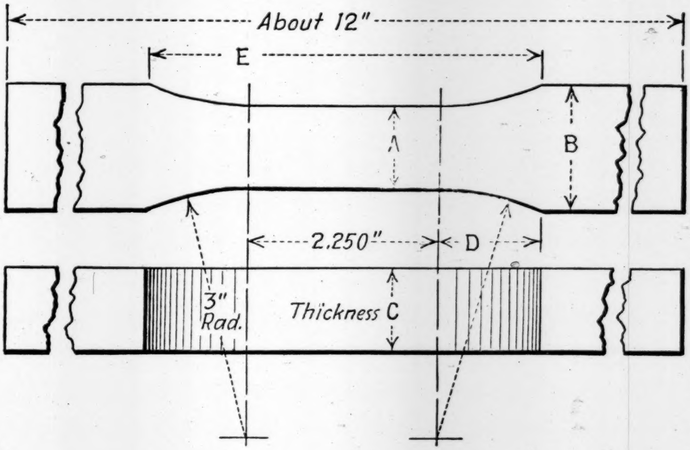
Modulus of Elasticity.

8. When it is desired to obtain the modulus of elasticity, a suitable extensometer measuring the elongation on a 2-in. gage length shall be used. The cross-head speed of the testing machine shall not exceed 0.03 in. per minute when the machine is running idle.

Procedure.

9. Strain readings shall be taken by increments of load not exceeding about 1000 lb. per sq. in. The modulus shall be calculated from the total change of length between zero load and stress of 5000 lb. per sq. in.

NOTE.—For some materials the stress strain curve will not form a straight line, but will be a continuous curve from the origin to the breaking load.



When C is less than $\frac{1}{8}$ in., A is $\frac{1}{2}$ in., B is $\frac{3}{4}$ in., D is 0.857", E is 3.964 in.
When C is $\frac{1}{8}$ in. or over, A is 1 in., B is $1\frac{1}{2}$ in., D is 1.199", E is 4.648 in.

FIG. 1.—Tension Test Specimen for Laminated Sheet Insulating Materials.

Report.

10. The report shall include the following:

(*a*) The direction in which the specimen was taken, whether lengthwise or crosswise of the sheet.

(*b*) The thickness and width of each specimen in inches or centimeters.

(*c*) The breaking load of each specimen, in pounds or kilograms.

(*d*) The tensile strength of each specimen, in pounds per square inch or in kilograms per square centimeter.

(*e*) The location and nature of the fracture.

(*f*) The modulus of elasticity, if determined.

(*g*) The room temperature.

FLEXURAL STRENGTH

(FORMERLY CALLED TRANSVERSE STRENGTH)

(*A*) *For Materials $\frac{1}{32}$ in. Thick or Over*[1]

Apparatus. 11. (*a*) Any standard type of testing machine may be used. The machine shall have an accuracy of at least 1 per cent of the lowest load for which it is used.

(*b*) The specimen shall be tested as a simple beam loaded at the center. The supports shall have contact edges rounded to a radius of $\frac{1}{8}$ in. for material $\frac{1}{8}$ in. or over in thickness, and to a radius of $\frac{1}{16}$ in. for thinner materials. For material thinner than $\frac{1}{8}$ in. both supports shall be provided with a pin or other stop to align one side of the specimen perpendicular to the line of contact with the supports. The distance between the points of support shall be 4 in. for edgewise tests of all thicknesses and eight times the nominal thickness of the material to be tested for tests in the flatwise direction, except that the minimum span shall be $\frac{1}{2}$ in.

Specimen. 12. The test specimen shall be $\frac{1}{2}$ in. in width except for specimens over $\frac{1}{2}$ in. in thickness tested in the flatwise direction, which shall have the width equal to the thickness of the specimen. The thickness shall be the full thickness of the sheet. The length shall be 1 in. greater than the distance between the points of support as specified in Section 11 (*b*).

Procedure. 13. The specimens shall be tested as follows:

(*a*) Five specimens cut lengthwise of sheet, tested flatwise.
(*b*) Five specimens cut lengthwise of sheet, tested edgewise.
(*c*) Five specimens cut crosswise of sheet, tested flatwise.
(*d*) Five specimens cut crosswise of sheet, tested edgewise.

Temperature of Tests. 14. All tests shall be made at normal room temperature of about 20° C. (68° F.).

Speed of Testing Machine. 15. The cross-head speed of the testing machine shall be such that the beam of the machine can be kept balanced, but shall not exceed 0.05 in. per minute when the machine is running idle.

Report. 16. The report shall include the following:

(*a*) The directions of cutting and loading of the specimen as specified in Section 13.

(*b*) The thickness and width of each specimen in inches or millimeters.

(*c*) The breaking load of each specimen in pounds or kilograms.

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[1] Conventional flexure tests in a flatwise direction are not recommended for materials thinner than $\frac{1}{32}$ in. nor in the edgewise direction for materials thinner than $\frac{1}{4}$ in.

(*d*) The maximum fiber stress in pounds per square inch or kilograms per square centimeter calculated from the formula:

$$S = \frac{3}{2}\frac{Pl}{bd^2}$$

where S = maximum fiber stress;
P = breaking load in pounds or kilograms;
l = distance between supports in inches or centimeters;
b = width of specimen in inches or centimeters;
d = depth of specimen in inches or centimeters.

(*e*) The room temperature.

COMPRESSIVE STRENGTH

Apparatus. 17. Any standard testing machine may be used provided it is accurate within 1 per cent of the lowest load for which it is used. One end of the specimen shall bear upon an accurately centered spherical bearing block, located whenever practicable, at the top, and the metal bearing plates shall be directly in contact with the ends of the test specimen. The pressure heads used for standard compression tests of cement as described in the Tentative Specifications and Tests for Compressive Strength of Portland-Cement Mortars (A.S.T.M. Designation: C 9 – 16 T) of the American Society for Testing Materials[1] are satisfactory for this test.

Specimen. 18. (*a*) For sheets 1 in. in thickness or over, the test specimen shall be a 1-in. cube, the faces of which shall be flat and perpendicular to the axes, being ground to this condition if necessary.

(*b*) For sheets less than 1 in. in thickness, the specimen shall consist of a pile of sheets 1 in. square with a minimum number of layers to produce a height of at least 1 in.

Procedure. 19. (*a*) For sheets 1 in. in thickness or over, three specimens shall be crushed in the condition in which they are received with the load applied flatwise, three specimens with the load applied edgewise-lengthwise of the sheet and three specimens with the load applied edgewise-crosswise of the sheet.

(*b*) For sheets less than 1 in. in thickness, three specimens shall be crushed in the condition in which they are received with the load applied flatwise of the sheet.

20. The load shall be applied on the ends of the specimen and the crosshead speed of the testing machine shall be such that the load can be accurately weighed but shall not exceed 0.050 in. (1.27

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[1] *Proceedings*, Am. Soc. Testing Mats., Vol. XX, Part I, p. 599 (1920); also 1930 Book of A.S.T.M. Tentative Standards, p. 164.

mm.) per minute when the machine is running idle. For the best results use the slowest possible speed.

Report. 21. The report shall include the following:

(*a*) The dimensions of each specimen in inches or millimeters,

(*b*) The direction of application of the load;

(*c*) The load on each specimen in pounds or kilograms at the first sign of failure;

(*d*) The ultimate compressive strength in pounds per square inch or kilograms per square millimeter, of each specimen, calculated from the area of each specimen measured before the load is applied;

(*e*) The general character of the material tested; with a description of how it acts under the applied load.

WATER ABSORPTION TESTS

Scope. 22. The water absorption tests are intended to determine the rate at which water is absorbed by the material when immersed, the total quantity absorbed at saturation, and the volatile content as received.

NOTE.—The electrical properties of different materials are not necessarily affected to the same extent by the same increase in moisture content so that the water absorption test must be correlated with the desired electrical tests.

The water immersion test and exposure to air of high humidity are not always directly comparable and should be considered before substituting one for the other.

(*A*) *Rate of Absorption*

Specimen. 23. The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches to the nearest 0.001 in. shall be measured on the original specimen at the center.

Procedure. 24. To determine the rate of absorption, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately re-weighed. The difference between the original weight and the dry weight shall be recorded as loss in weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 2 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. If the specimen is $\frac{1}{16}$ in. in thickness or less it shall be weighed in a weighing bottle. The difference between the weight of the wet specimen and that of the dry specimen shall be recorded as the weight of water absorbed in 2 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen.

(*c*) After 24 hours immersion the specimen shall again be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed. The difference between the weight of the specimen after 24 hours immersion and the weight of the dry specimen shall be recorded as the water absorbed in 24 hours. The percentage of water absorbed shall be calculated on the weight of the dry specimen. If the individual 24-hour absorptions differ by more than 10 per cent from the average absorption of the two specimens the test shall be repeated.

Report.

25. The report shall include the values for each of the two specimens and the average values as follows:

(*a*) The thickness of the specimen before the test, to the nearest 0.001 in.;

(*b*) The percentage loss in weight on drying calculated on the original weight;

(*c*) The percentage of water absorbed in 2 hours and in 24 hours calculated on the dry weight.

(*B*) *Total Absorption at Saturation*

Specimen.

26. (*a*) The test specimen shall be 3 by 1 in. by the thickness of the material. It shall be sawed or sheared from the sample so as to have smooth edges free from cracks. The cut edges of all test specimens shall be finished with No. 0 or finer sandpaper or emery cloth. Sawing and sandpapering operations should be slow enough so that the material is not heated appreciably. The thickness in inches measured to the nearest 0.001 in. shall be measured on the original specimen at the center and on the reduced specimen in case a reduced specimen is used (see Paragraph (*b*)).

(*b*) When the sample for determining total absorption is so thick that too long a time is required for saturation using the full thickness, the thickness may be reduced as follows: The sample shall be machined to a thickness of about $\frac{5}{64}$-in., both surfaces parallel to the laminations being machined off. This may readily be done with a smooth-cut circular saw. It shall then be sanded to $\frac{1}{16}$ in. in thickness, finishing with No. 0 or finer sandpaper. While the sanded surfaces of the sample should be approximately parallel with the laminations, the thickness may vary ±0.010 in., since the object is to provide comparable specimens which will reach saturation in a reasonable time. The machined and sanded sample shall then be cut into specimens 3 by 1 in. and the edges sanded.

Procedure. 27. To determine the total water absorption at saturation, two specimens shall be tested individually as follows:

(*a*) The specimen shall be weighed, dried in an oven for 1 hour at from 105 to 110° C., cooled in a desiccator and immediately reweighed. The difference between the original weight and the dry weight shall be recorded as loss of weight on drying. The percentage loss in weight shall be calculated on the original weight.

(*b*) The dried specimen shall then be immersed in distilled water at a temperature of from 20 to 30° C. At the end of 24 hours the specimen shall be removed from the water, the surface water wiped off with a dry cloth and the specimen weighed immediately and then replaced in the water. The weighings shall be repeated every day for the first week and every week thereafter until the increase in weight, as shown by three consecutive weighings, averages less than 1 per cent of the total increase in weight, when the specimen shall be considered to be saturated.

(*c*) The difference between the saturated weight and that of the dry weight shall be considered as the water absorbed at saturation. The percentage of water absorbed shall be calculated on the dry weight of the specimen.

Report. 28. This report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of material, measured to the nearest 0.001 in.;

(*b*) If a reduced specimen is used, the thickness measured to the nearest 0.001 in.;

(*c*) The percentage loss in weight on drying, calculated on the original weight;

(*d*) The percentage of water absorbed at saturation, calculated on the dry weight.

(*C*) *Volatile Matter*

Specimen. 29. The test specimen shall conform to the requirements specified in Section 12.

Procedure. 30. To determine the volatile matter, two specimens shall be tested individually as follows:

The specimen shall be weighed, dried in an oven at from 105 to 110° C. until the decrease in weight as shown by two consecutive weighings at least 24 hours apart is less than 1 per cent of the total decrease in weight. The difference between the original weight and the dry weight shall be recorded as the volatile matter present in the specimen as received (this includes in addition to water any volatile solvent left during manufacture). The percentage of volatile matter shall be based on the weight of the dry specimen.

Report.

31. The report shall include the values for each of the two specimens as follows:

(*a*) The original thickness of the material measured to the nearest 0.001 in.;

(*b*) The percentage of volatile matter, based on the weight of the dry specimen.

DIELECTRIC STRENGTH

Dielectric Strength.

32. The dielectric strength shall be determined in accordance with the Tentative Methods of Testing Sheet and Tape Insulating Materials for Dielectric Strength (A.S.T.M. Designation: D 149 – 30 T) of the American Society for Testing Materials.[1]

PHASE DIFFERENCE (POWER FACTOR) AND DIELECTRIC CONSTANT

Dielectric Constant.

33. The phase difference and dielectric constant shall be determined in accordance with the Tentative Methods of Testing Electrical Insulating Materials for Power Factor and Dielectric Constant at Frequencies of 100 to 1500 Kilocycles (A.S.T.M. Designation: D 150 – 27 T) of the American Society for Testing Materials.[2]

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[1] See p. 1188.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 27, Part I, p. 1003 (1927); also 1930 Book of A.S.T.M. Tentative Standards, p. 554.

TENTATIVE METHOD OF TEST FOR COMPARING THE THERMAL CONDUCTIVITIES OF SOLID ELECTRICAL INSULATING MATERIALS[1]

A.S.T.M. Designation: D 325 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1930.

Scope. 1. This method is intended for comparing the thermal conductivities of solid electrical insulating materials which are in the form of flat sheets. An accuracy of 5 per cent can be obtained with this method.

Definition. 2. *Thermal Conductivity.*—The thermal conductivity of a homogeneous material is the rate of heat flow under steady conditions, per unit area, and per unit temperature gradient in the direction perpendicular to the area. Thermal conductivity is expressed in watts per square centimeter per degree centigrade per centimeter.

Principle. 3. The principle of the method is analogous to the potentiometer method of comparing electrical resistances. A specimen of unknown conductivity is placed in series with a standard specimen of known conductivity between plates which are maintained at different temperatures. When a steady state of heat flow is attained, the respective temperature differences across the standard and the test specimens are measured and the conductivity of the test specimen is calculated from the following relation:

$$K = K_1 \frac{L}{L_1} \times \frac{\Delta t_1}{\Delta t}$$

where K = the conductivity of the test specimen;
K_1 = the conductivity of the standard specimen;
L = the thickness of the test specimen;
L_1 = the thickness of the standard specimen;
Δt = the temperature difference of the test specimen;
Δt_1 = the temperature difference of the standard specimen.

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[1] Criticisms of this Tentative Method are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electric Co., Schenectady, N. Y.

APPARATUS

4. The apparatus, consisting of a heating plate, a cooling plate, three or four thermocouples, a calibrated galvanometer or a thermocouple potentiometer, an ice bath, and at least one standard specimen, shall conform to the following requirements: **Apparatus.**

(*a*) *Plates*—The heating and the cooling plates shall be flat pieces of metal. The contact surface of each plate shall have dimensions equal to or greater than the contact surface of the specimen. The metal surface which supplies or removes the heat from the specimens shall be maintained at a temperature which is constant and uniform within 0.1° C.

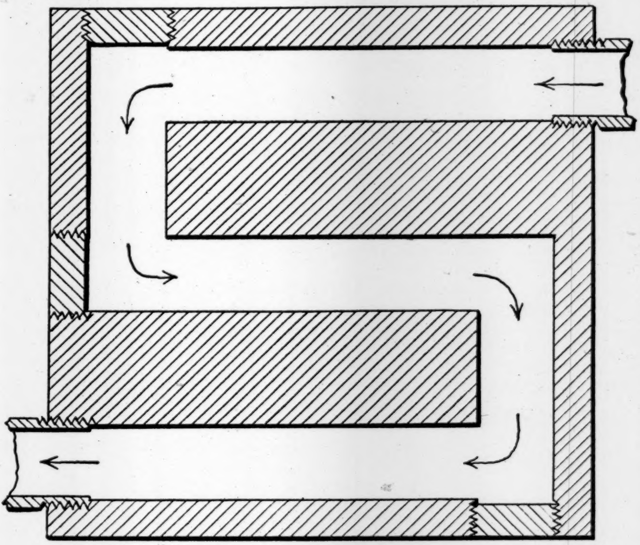

FIG. 1.—Cross-section of Heating or Cooling Plate.

NOTE.—The heating plate may be heated either electrically or by the vapor from a liquid boiling at a definite temperature. The cooling plate may be cooled by a liquid circulating through it. A platen from a steam-heated press makes a satisfactory heating or cooling plate. A plate of this description is shown in Fig. 1.

(*b*) *Thermocouples*.—The measuring junction or hot junction of each thermocouple shall be made of thin copper foil approximately 2.5 cm. (1.0 in.) square, to which two thermocouple wires shall be soldered, one of copper and one of a suitable alloy. The thickness of the copper foil shall be approximately 0.15 mm. (0.006 in.) and the wires shall have approximately the same diameter as the thickness of the foil. The joints between the wire and the foil shall be flattened to a thickness about the same as that of the foil. The reference junction or cold junction shall be made by soldering a copper wire to the opposite end of the alloy wire. This junction shall be mounted in a glass tube not more than 0.25 cm. (0.1 in.) in diameter which is sealed at its lower end and immersed in the ice bath so that the junction is at least 10 cm. (4 in.) below the surface.

The unconnected ends of the copper wires shall be the terminals of the thermocouple.

(*c*) *Galvanometer.*—If a galvanometer is used on the terminals of the thermocouples it shall have a sensitivity sufficient to indicate definitely a change of temperature of 0.1° C. at the hot junction of any of the thermocouples. The deflections of the galvonometer shall be sufficiently steady and the instrument shall be calibrated to warrant an accuracy of ±0.25° C.

(*d*) *Potentiometer.*—If a potentiometer is used on the terminals of the thermocouples it shall be sufficiently sensitive and precise to warrant an accuracy of ±0.25° C.

(*e*) *Ice Bath.*—The ice bath shall consist of a Dewar flask or other well-insulated vessel filled to a depth of at least 15 cm. (6 in.) with ice and water.

SPECIMENS

Test Specimens.

5. (*a*) Test specimens shall be in the form of flat sheets which may be square, circular, or rectangular in shape. The specimens shall not project beyond the edges of the heating or cooling plates and the total thickness of a test specimen and a standard specimen shall not exceed one-sixth of the edge of the square, the diameter of the circle or the shortest side of the rectangle.

(*b*) A convenient size for test specimens is approximately 20 cm. (8 in.) square and 1 cm. (0.4 in.) in thickness. The thickness of the specimen shall be measured at its midpoint with an accuracy of ±1 per cent. When the material is soft or easily compressible, the measurement shall be made in such a way as to indicate the thickness under the pressure used in the test.

Standard Specimens.

6. (*a*) Standard specimens shall have the same shape and size as the test specimens. Any test in which the conductivity of the test specimen is found to be less than one-half or more than twice the conductivity of the standard specimen to which it was compared shall be tested again using another standard specimen having a conductivity nearer that of the specimen under test. Standard specimens may be made from materials the thermal conductivity of which is reasonably permanent and unaffected by changes in atmospheric humidity.

(*b*) Standard specimens shall be certified, by a standardizing laboratory, for thermal conductivity with an accuracy of ±2 per cent.

NOTE.—Standard specimens having considerable ranges of conductivities may be made from a rubber in which graphite is incorporated as a filler in varying amounts. Specimens have been made from a base compound of high rubber content and different proportions of 300-mesh pure graphite.

The composition of the base compound was as follows:

Plantation rubber, per cent	96.0
Zinc oxide, per cent	1.0
Stearic acid, per cent	0.75
Tetramethylthiuram disulfide, per cent	0.25
Sulfur, per cent	2.00
Total	100.00

The conductivities of the specimens were as follows:

GRAPHITE, PER CENT	THERMAL CONDUCTIVITY, WATTS, CM. $^{-1}$ (DEG. CENT) $^{-1}$
0	0.00143
15	0.00183
30	0.00248
45	0.00383
60	0.00824

PROCEDURE

The Mounting of Plates and Specimens.

7. (*a*) The heating and the cooling plates and the specimens shall be placed in a horizontal position, one on top of the other. The order of assembly from the top down shall be as follows:

(1) Heating plate;
(2) Thin rubber sheet;
(3) Measuring junction of a thermocouple;
(4) Test specimen;
(5) Measuring junction of a thermocouple;
(6) Thin rubber sheet;
(7) Measuring junction of a thermocouple;
(8) Standard specimen;
(9) Measuring junction of a thermocouple;
(10) Thin sheet of rubber;
(11) Cooling plate.

(*b*) The pressure on the specimens shall be 25 g. per sq. cm. (50 lb. per sq. ft.).

(*c*) The assembled plates and test specimens shall be enclosed on all sides by at least 2 in. of good thermal insulating material in order to minimize the heat loss at the edges.

NOTE.—The thin sheet of rubber, which has a thickness of about 0.25 mm. (0.01 in.), is required to insure good thermal contact between hard surfaces. Ordinary "dental dam" is a suitable and readily obtainable sheet for this purpose. When the standard specimen and the test specimen are soft and flexible, the rubber sheet and thermocouple may be omitted.

Procedure.

8. (*a*) *Temperature of the Plates.*—The heating and the cooling plates shall be maintained at temperatures which are constant within ±0.1° C. until the temperature differences across the specimens being compared are constant within ±0.25° C. for one hour.

(*b*) *Temperature of Specimens.*—The mean of the temperatures at the two surfaces of the test specimen shall be considered the temperature of the specimen and shall be within ±10° C. of the temperature at which it is desired to know the thermal conductivity. Similarly, the mean of the temperatures at the two surfaces of the standard specimen shall be considered its temperature.

The temperature of the standard specimen shall be within ±10° C. of a temperature at which its thermal conductivity is known. The temperature difference across any specimen shall not be greater than 50° C. nor less than 10° C.

Calculations.

9. The thermal conductivity of the test specimen shall be calculated by the formula given in Section 3.

NOTE 1.—The thermal conductivity of most materials increases with increasing temperature. The temperature coefficient near room temperature is usually within the range of 0.002 and 0.005 per 1° C. The change of thermal conductivity with temperature is usually near enough to a linear relation to permit the mean temperature of a specimen to be used even when large temperature differences exist.

NOTE 2.—Temperatures in the specimens being compared may be made approximately those desired by the selection of appropriate temperatures for the heating and the cooling plates, and by the insertion of sheets of thermal insulating material in the test assembly. The total thickness of these accessory sheets and of the specimens being compared should not exceed the thickness specified in Section 5 as the total thickness of a test specimen and a standard specimen.

NOTE 3.—A temperature of 70° C. is recommended as the temperature at which the thermal conductivity of electrical insulating materials should be measured since many such materials are designed for use at 40° C. above room temperature.

REPORT

Report.

10. The report shall include the following:

(*a*) The standard specimen used;
(*b*) The thickness of the standard specimen;
(*c*) The thickness of the test specimen;
(*d*) The temperatures at the top and bottom of the test specimen;
(*e*) The temperatures at the top and bottom of the standard specimen;
(*f*) The computed conductivity of the test specimen and its mean temperature.

TENTATIVE SPECIFICATIONS
FOR
CHAFER TIRE FABRICS[1]

A.S.T.M. Designation: D 316 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1929; REVISED, 1930.

Scope.

1. These specifications cover commercial 8, 9, 12 and 14-oz. chafer tire fabrics made of carded American cotton, of the following constructions:

8 oz.	20/3 ply	(in both warp and filling)....	1 to 1$\frac{1}{16}$-in.	staple	commercial	cotton
	14/2 ply	(" " " " ")....	$\frac{15}{16}$ to 1-in.	"	"	"
9 oz.	20/4 ply	(" " " " ")....	1 to 1$\frac{1}{16}$-in.	"	"	"
	10/2 ply	(" " " " ")....	$\frac{15}{16}$ to 1-in.	"	"	"
12 oz.	12/4 ply	(" " " " ")....	$\frac{15}{16}$ to 1-in.	"	"	"
14 oz.	20/8 ply	(" " " " ")....	1 to 1$\frac{1}{16}$-in.	"	"	"
	10/4 ply	(" " " " ")....	$\frac{15}{16}$ to 1-in.	"	"	"

Properties.

2. Chafer tire fabric shall conform to the requirements specified in Table I, subject to the tolerances specified in Sections 1 to 8 of the Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (A.S.T.M. Designation: D 122) of the American Society for Testing Materials.[2]

Methods of Testing.

3. With the exception of the tensile strength determination, all test procedures shall be conducted in accordance with Sections 10 to 17 of the Standard Specifications for Tolerances and Test Methods for Tire Fabrics Other than Cord Fabrics (A.S.T.M. Designation: D 122) of the American Society for Testing Materials.[2] The tensile strength shall be determined by the Grab Test in accordance with

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[1] Criticisms of these Tentative Specifications are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

[2] 1930 Book of A.S.T.M. Standards, Part II, p. 1081.

Sections 11 and 12 of the Standard General Methods of Testing Woven Textile Fabrics (A.S.T.M. Designation: D 39)[1] and the speed of the pulling jaw shall be 12 in. per minute.

TABLE I.—PHYSICAL PROPERTIES OF CHAFER TIRE FABRICS.

			8-oz. Fabric		9-oz. Fabric		12-oz. Fabric	14-oz. Fabric	
			20/3 Ply Construction	14/2 Ply Construction	20/4 Ply Construction	10/2 Ply Construction	12/4 Ply Construction	20/8 Ply Construction	10/4 Ply Construction
Width, in.			48, 54 or 60	48, 54 or 60	48, 54 or 60	48, 54 or 60	48, 54 or 60	48, 54 or 60	48, 54 or 60
Weight, oz. per sq. yd.			8.1	8.1	9.25	9.25	12.0	14.30	14.30
Count		Warp	35	37	29	29	22.5	22.5	22.5
		Filling	37	39	31	31	23.5	23.5	23.5
Thickness (Gage), in.			0.023	0.023	0.0275	0.0275	0.033	0.038	0.038
Tensile Strength,[a] lb.	Grab Test, Conditioned[b]	Warp	110	100	130	115	145	200	185
		Filling	120	110	140	125	155	210	195
	Grab Test, Bone dry[c]	Warp	80	70	85	75	100	135	120
		Filling	85	75	95	85	110	145	130
Ply Twist		Warp	11.0	11.0	7.5	8.5	6.5	5.0	5.5
		Filling	11.0	11.0	7.5	8.5	6.5	5.0	5.5
Crimp, per cent		Warp	16	16	16	16	16	16	16
		Filling	8	8	8	8	8	8	8

[a] Values of tensile strength are the minimum average.
[b] Preferred Method.
[c] Alternate Method.

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[1] 1930 Book of A.S.T.M. Standards, Part II, p. 1102.

TENTATIVE METHODS FOR IDENTIFICATION OF TEXTILE FIBERS AND THEIR QUANTITATIVE DETERMINATION IN MIXED GOODS[1]

A.S.T.M. Designation: D 276 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1927; Revised, 1929, 1930.

General Characteristics and Appearance of the Most Important Textile Fibers

Cotton:

Cotton, including several different kinds, consists of seed hairs obtained from different species of plants of the genus *Gossypium.* The kinds most used are American Upland cotton from *Gossypium hirsutum,* Sea Island from *Gossypium barbadense,* Egyptian supposed to be from a hybrid derived in part from *Gossypium barbadense,* India cotton from *Gossypium herbaceum* and Chinese cotton from *Gossypium nanking.*

Normal cotton fibers appear as long, colorless, twisted, ribbon-like cellular structures with thickened edges, due to the collapse of the original hollow cylindrical structure or tube. Most fibers have a flattened central air-filled canal or lumen. The length of the fibers varies with the variety from about ½ to 2 in. and the diameter or ribbon width from about 0.00063 to 0.00090 in. The number of natural twists or convolutions along the fibers varies considerably, ranging from about 159 to 225 per in. These twists occur in both directions.

Flax or Linen:

Flax fibers are bast fibers from the inner bark of the flax plant, *Linum usitatisaimum.*

Flax fibers consist of groups of cells, and these ultimate cells are long pointed, colorless and fairly uniform in structure. The central lumen often indistinct and sometimes appearing double, is narrow compared with the thickness of the cell wall.

Characteristic slight swellings or nodes are to be found at fairly regular intervals, with fine almost invisible cross-lines. The nodes, discolorations and cross-lines are more pronounced in woven fabrics than in raw flax, and recent studies indicate that the cross-lines which have been regarded as especially characteristic of flax, seem to be produced chiefly by the methods of extracting and cleaning the fiber.

Individual flax fibers vary in diameter, from coarse or fine stemmed plants and also depending on how much it has been combed or split up.

Commercial flax usually runs about 20 in. in length, but some fibers may run up to 36 in. or even longer. The ultimate cells of flax range from 15 to 50 mm. (0.6 to 2.0 in.) but in actual practice the fibers are rarely, if ever, reduced to their ultimate cells. In woven fabrics, linen yarns often show a characteristic abrupt change in diameter due to fibers being partly split off in hackling. In contrast to this, cotton yarns vary in size in a tapering manner.

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[1] Criticisms of these Tentative Methods are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

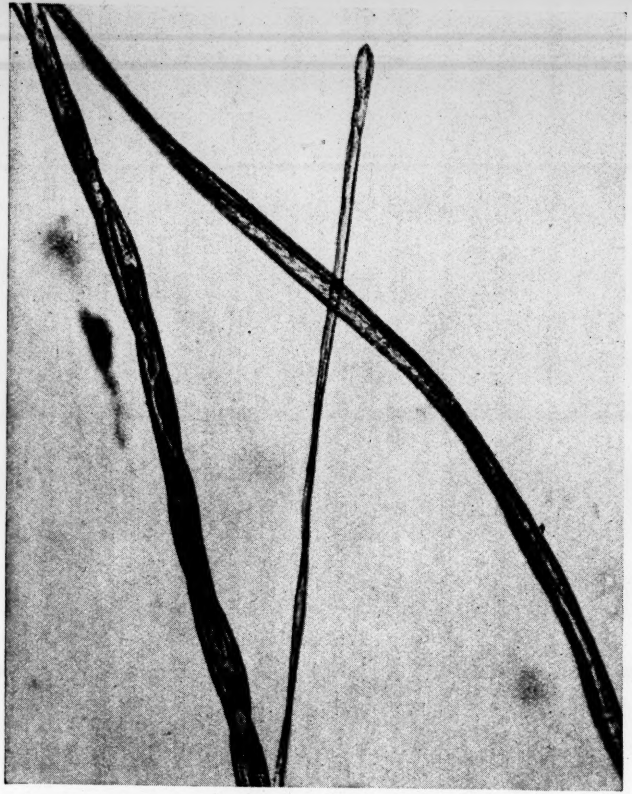

FIG. 1.—Longitudinal View of Cotton (× 250).

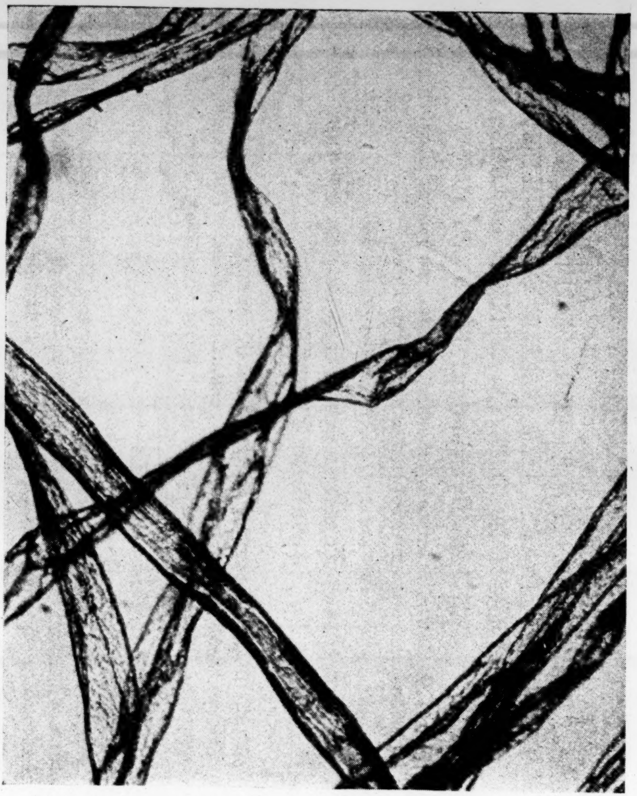

FIG. 2.—Longitudinal View of Immature Cotton (× 500).

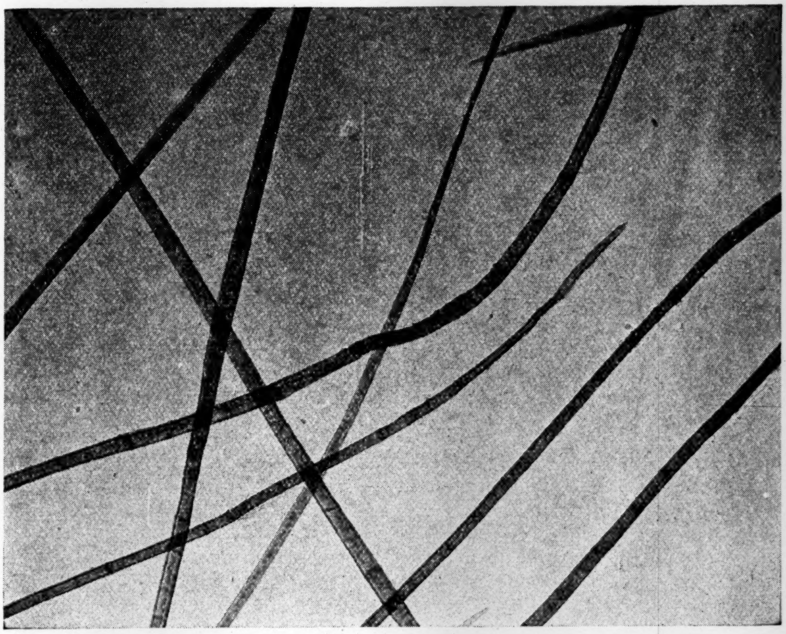

FIG. 4.—Longitudinal View of Hemp (*Cannabis Sativa*) (× 100).

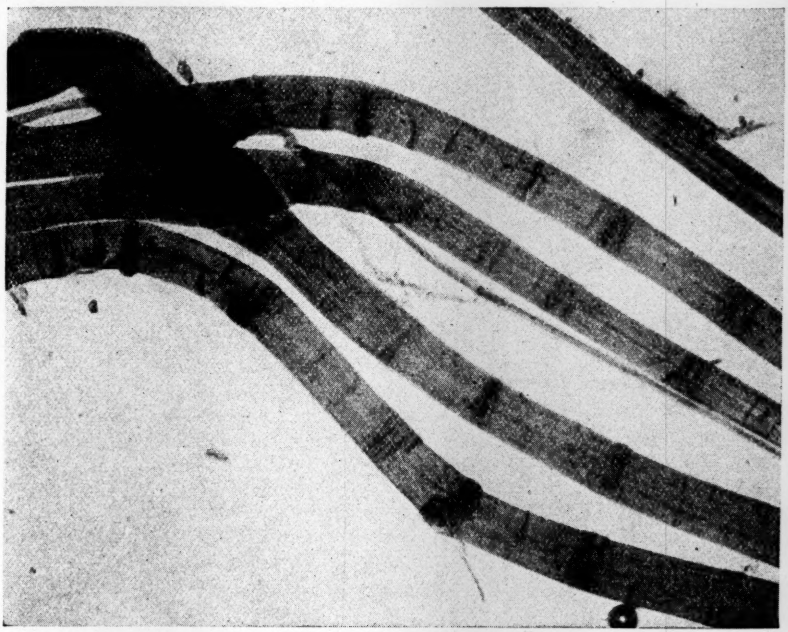

FIG. 3.—Longitudinal View of Flax or Linen Fibers (× 220).

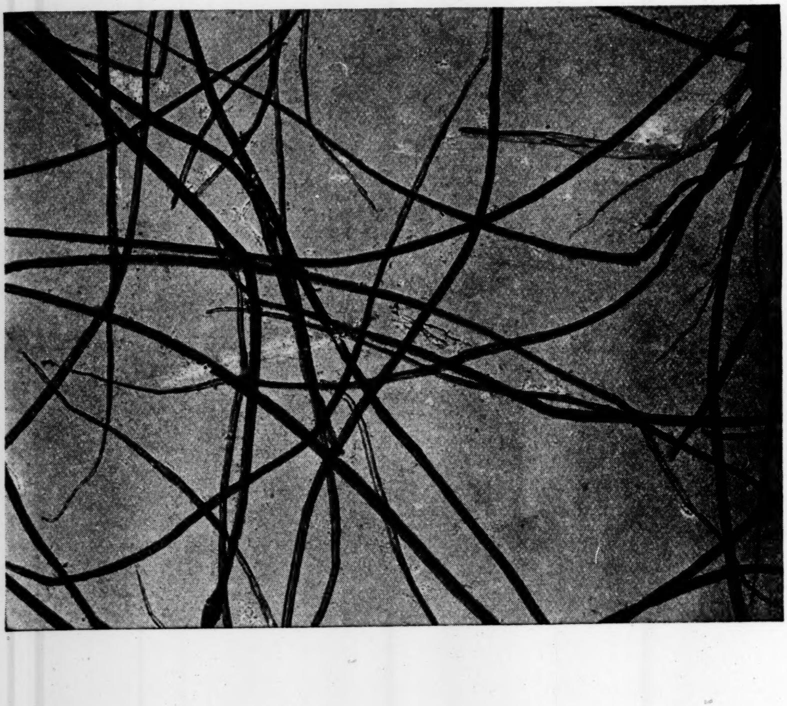

FIG. 5.—Longitudinal View of Jute (× 100).

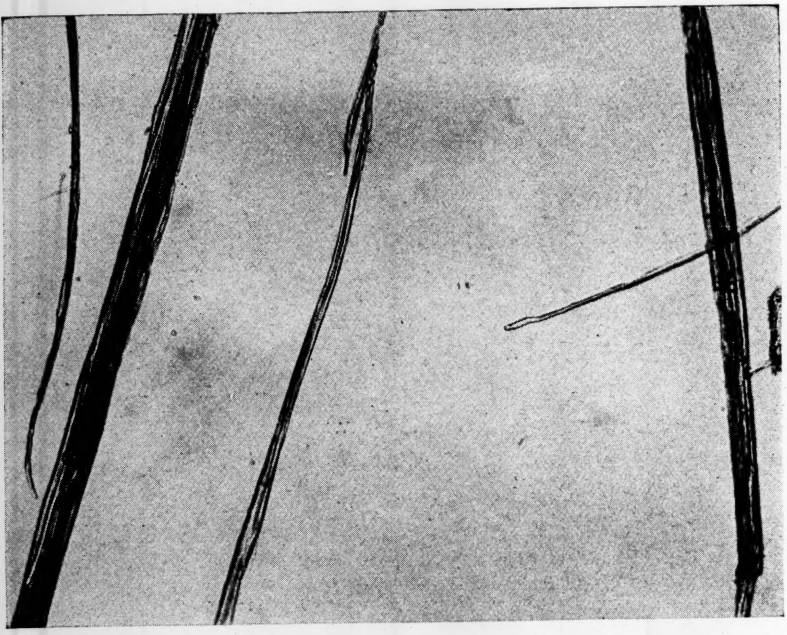

FIG. 6.—Longitudinal View of Jute (× 100).

Hemp (Common hemp, *Cannabis sativa*):

Hemp fibers are bast fibers from the inner bark of the hemp plant, *Cannabis sativa*.

Hemp fibers are composed of groups of long, blunt cells, not pointed at the ends as flax, though often of a forked shape. They all show large, well-defined lumens equal to or exceeding the thickness of the walls. There are usually pronounced longitudinal striations, and cross-lines are prominent, as are dislocations or folds, swellings and cross-fissures. The cell cross-sections are irregularly oval; the lumen flattened and irregular.

The commercial fibers are usually 3 to 8 ft. in length and in some kinds may be even longer. Dew-retted hemp is gray; water-retted hemp is light yellow; and steam or peeled and scraped hemp is semi-translucent.

There are several fibers miscalled hemp, but all are distinctly different from true hemp, and also different from each other. The following list indicates some of these fibers which are actually used in commerce:

Soft Fibers.............	Sunn Ambari Roselle
Hard Fibers............	Abaca (Manila Hemp) Henequen Sisal Cantala Pitera Mescal Jaumave Tula Palma

Jute:

Jute fibers are bast fibers from the inner bark of two closely related plants, India jute, *Corchorus capsularis*, and Desi jute, *Corchorus olitorius*.

Jute fibers appear as bundles of fibers, shorter than hemp, with tapering and more pointed ends than hemp. The lumen is oval shaped, almost central, large and well defined, at times as wide or wider than the cell-walls and often remarkably constricted. The cross-sections of the cells are polygonal, five or six sided. There are longitudinal striations but no transverse markings nor jointed ridges. Externally the fibers are smooth and lustrous.

The prepared fibers may run from 4½ to 8 ft. in length and the crude fibers may be as long as 14 ft.

Ramie (*Rhea*):

Ramie fibers are bast fibers from the inner bark of the ramie or rhea plant, *Boehmeria nivea*.

Ramie fibers are long, somewhat tapering cells of uneven diameter with thick rounded ends. The diameter is irregular and the central canal or medullary space is sometimes quite distinct and at other times disappearing entirely. The canals are filled with granular matter and occupy from one-third to one-half the diameter. In cross-section the cells are more or less irregularly elliptical, but are often flattened and show very characteristic prominent cross-lines or fissures. The cell-walls are coarse, thickened irregularly at intervals, usually

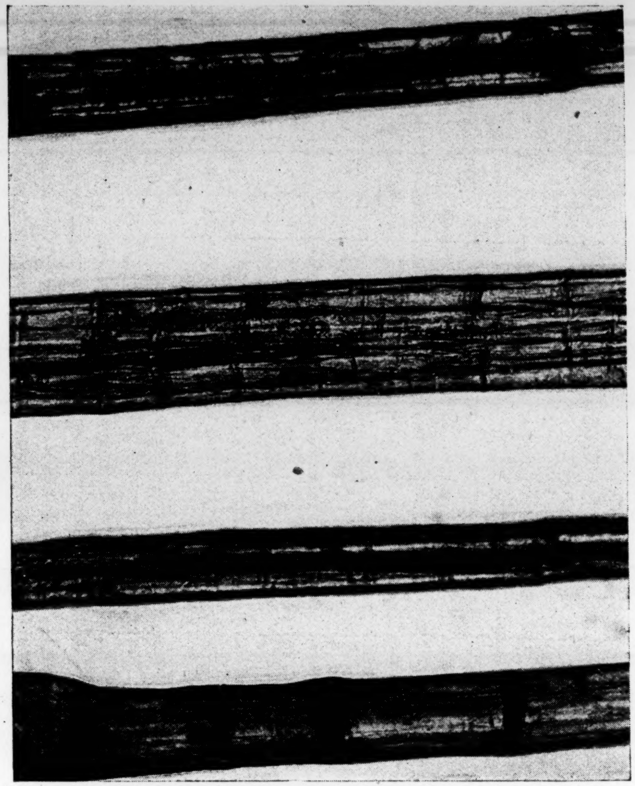

FIG. 7.—Longitudinal View of Ramie (× 250).

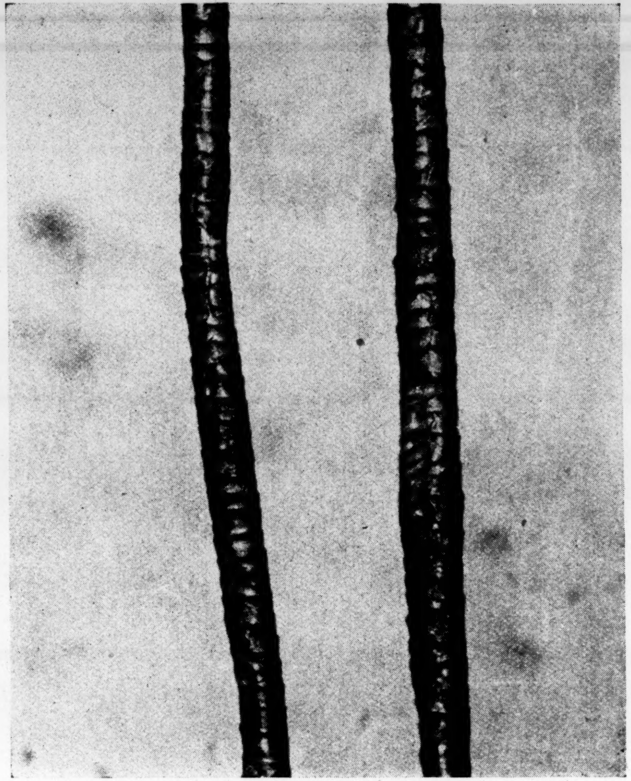

FIG. 8.—Longitudinal View of Wool (× 250).

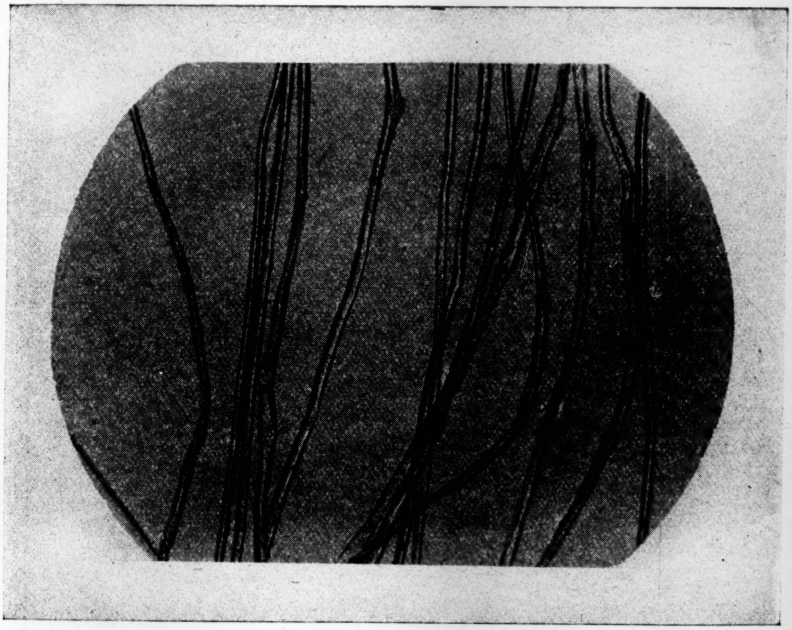

FIG. 9.—Longitudinal View of Silk (× 100).

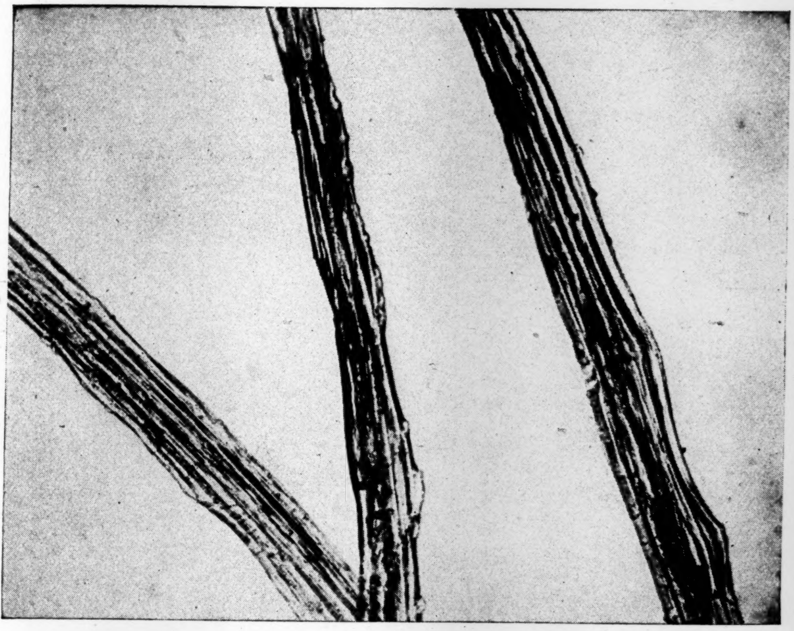

FIG. 10.—Longitudinal View of Raw Jap Silk (× 100).

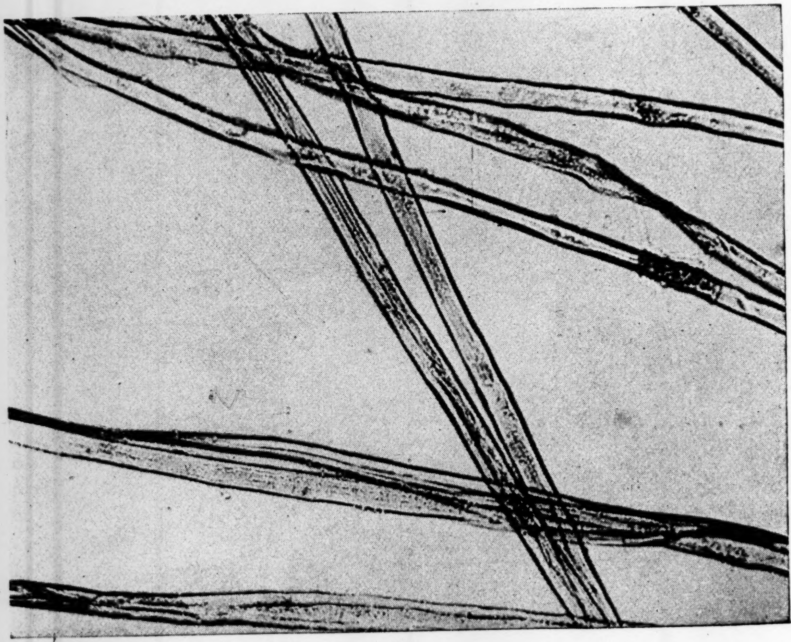

FIG. 11.—Longitudinal View of Tussah Silk (× 100).

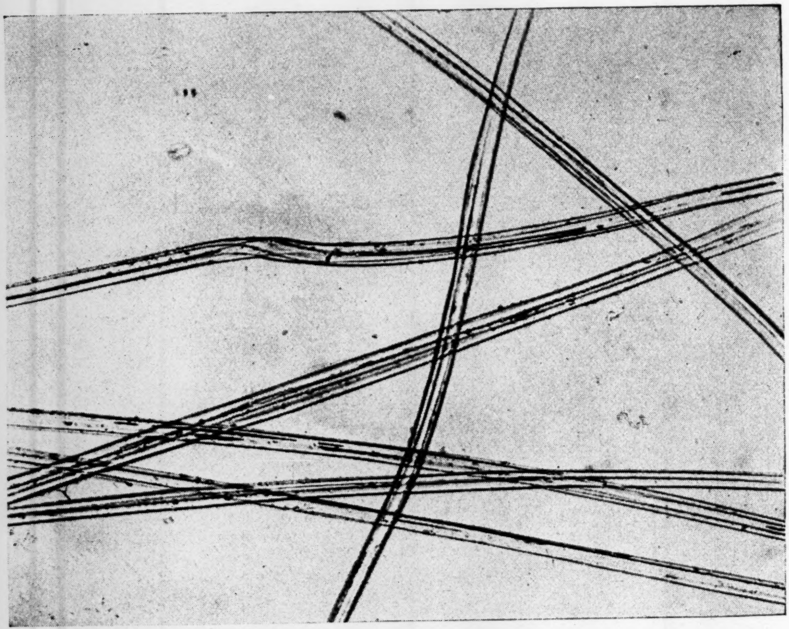

FIG. 12.—Longitudinal View of Cellulose Acetate Rayon (Celanese) (× 100).

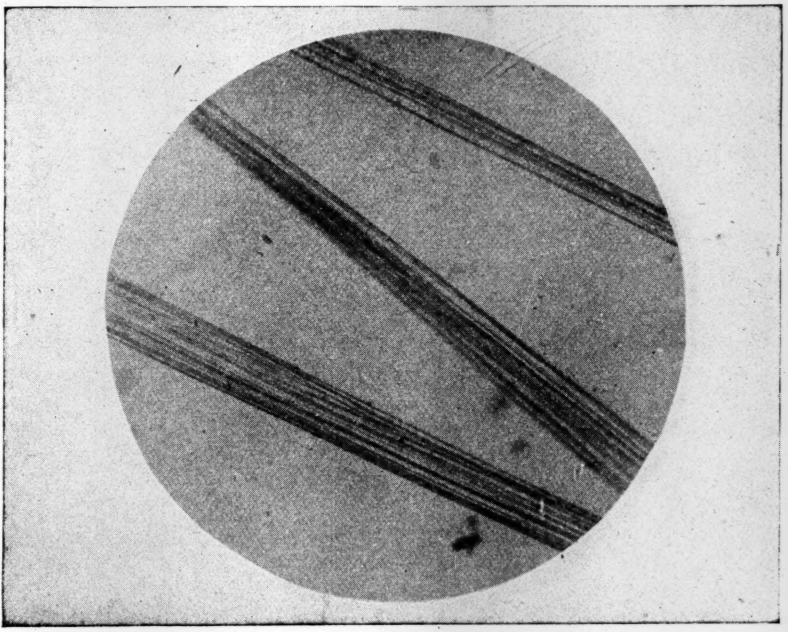

FIG. 13.—Longitudinal View of Xanthate of Cellulose Rayon (Viscose Co.) (× 100).

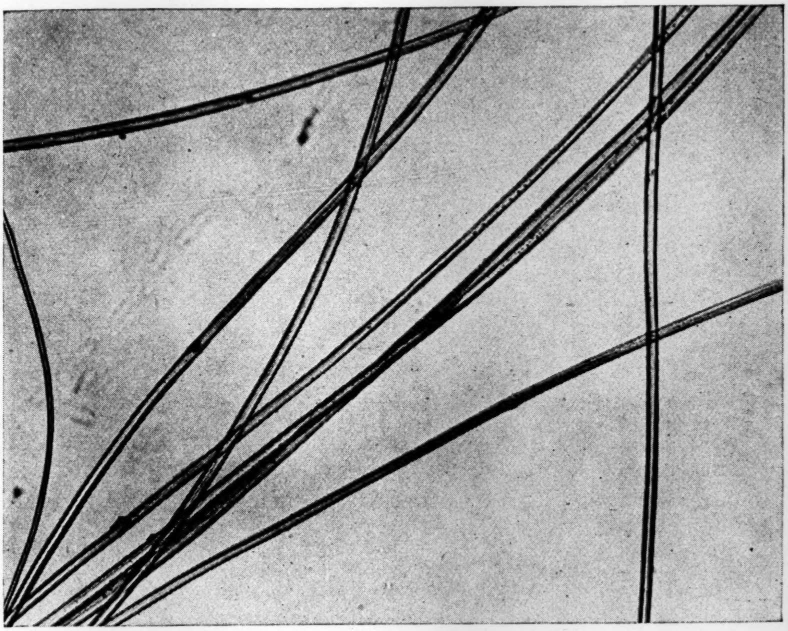

FIG. 14.—Longitudinal View of Cuprammonium Rayon (Bemberg) (× 100).

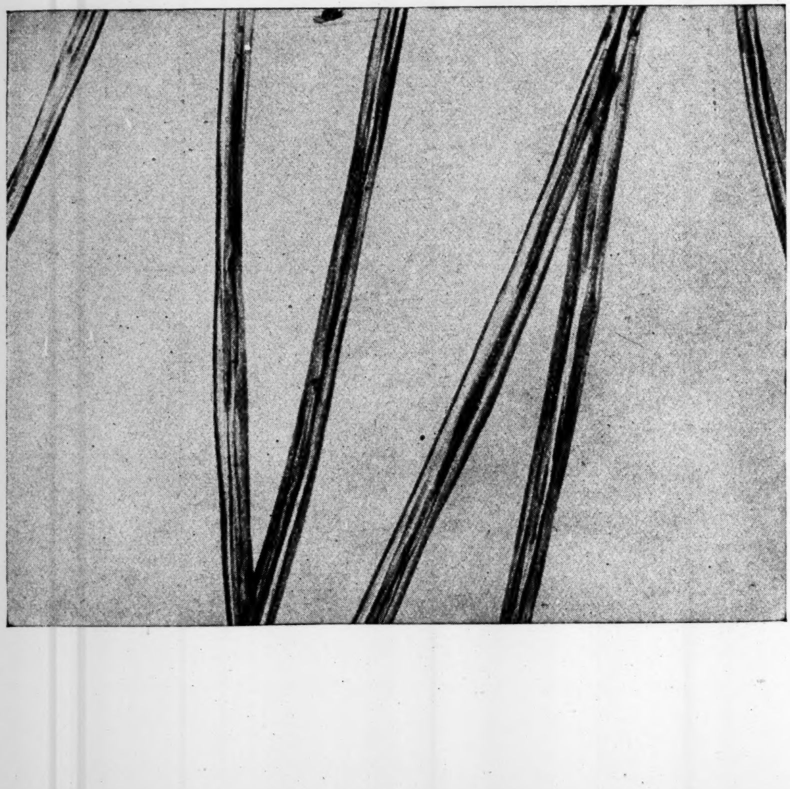

FIG. 15.—Longitudinal View of Nitro-cellulose Rayon (Tubize) (× 100).

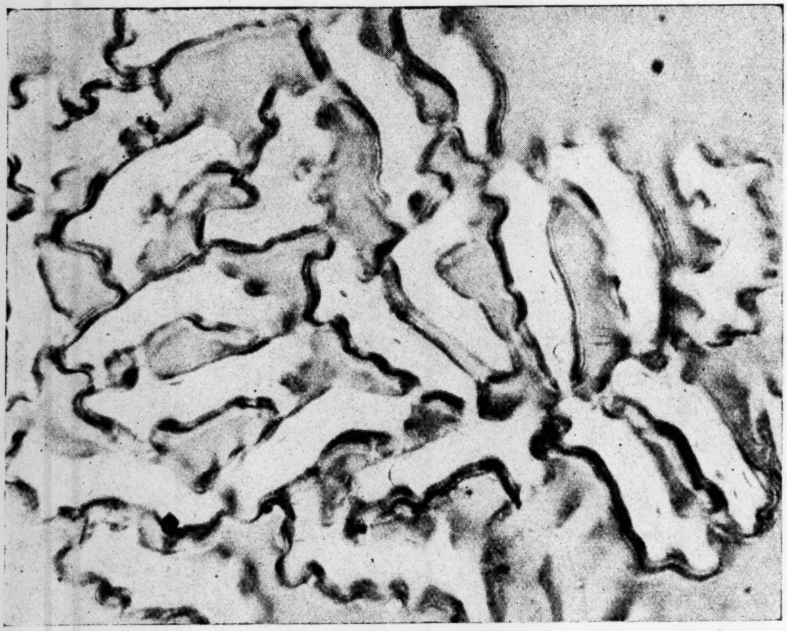

FIG. 16.—Cross-Section of Viscose Rayon, 150 Denier (DuPont Unbleached) (× 500).

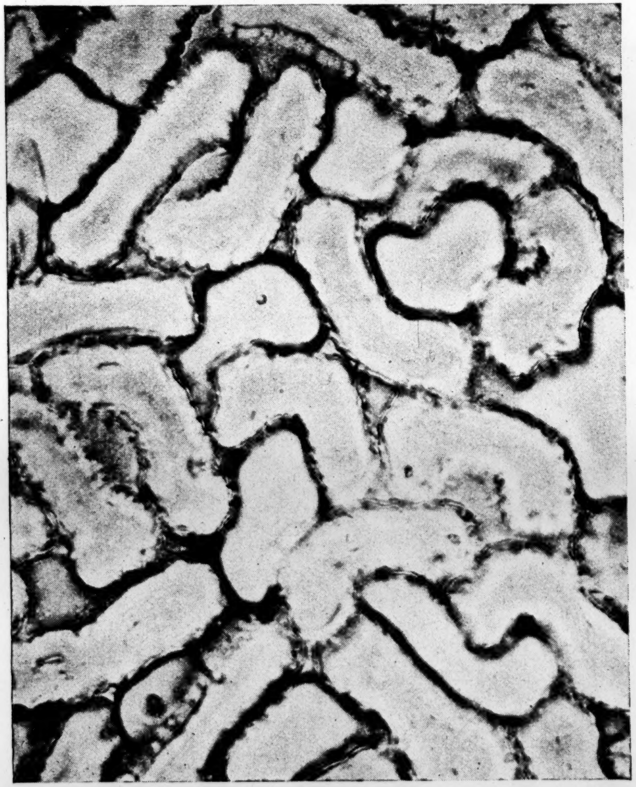

FIG. 17.—Cross-Section of Viscose Rayon, 300 Denier (Industrial Fiber Co.) (× 500).

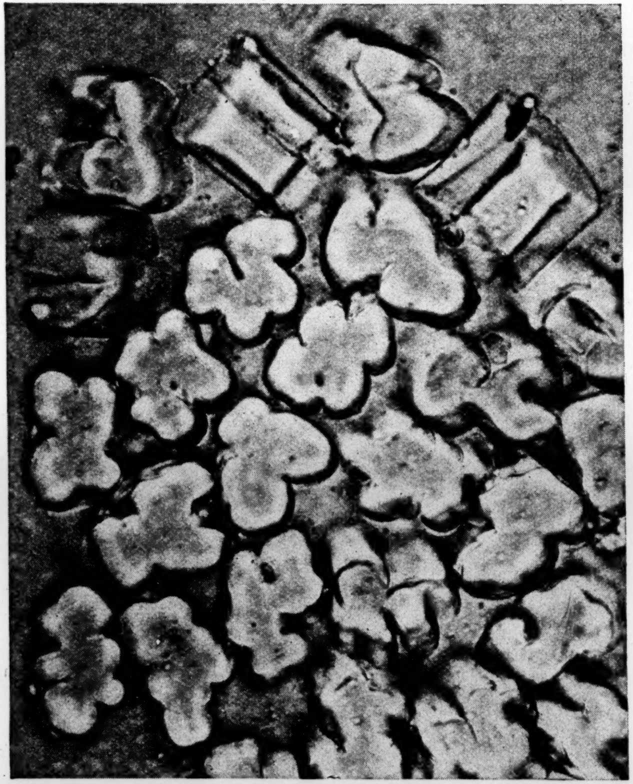

FIG. 18.—Cross-Section of Acetate Rayon, 150 Denier (Celanese) (× 500).

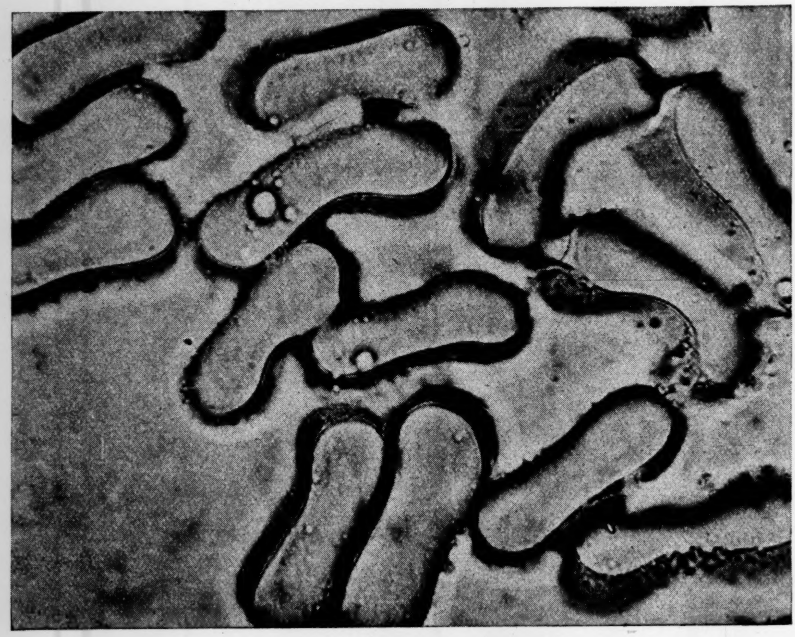

FIG. 19.—Cross-Section of Acetate Rayon, 150 Denier (Lustron Co.) (× 500).

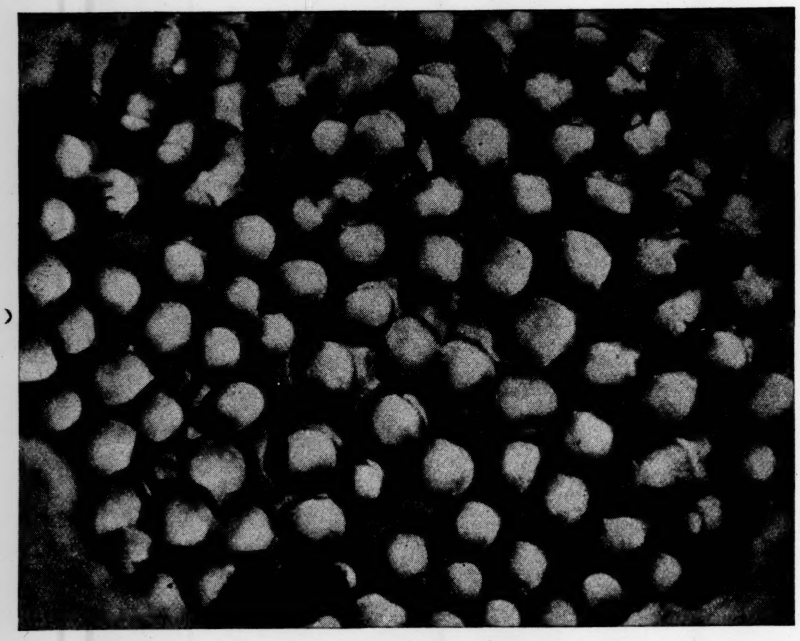

FIG. 20.—Cross-Section of Cuprammonium Rayon, 150 Denier (Bemberg) (× 500).

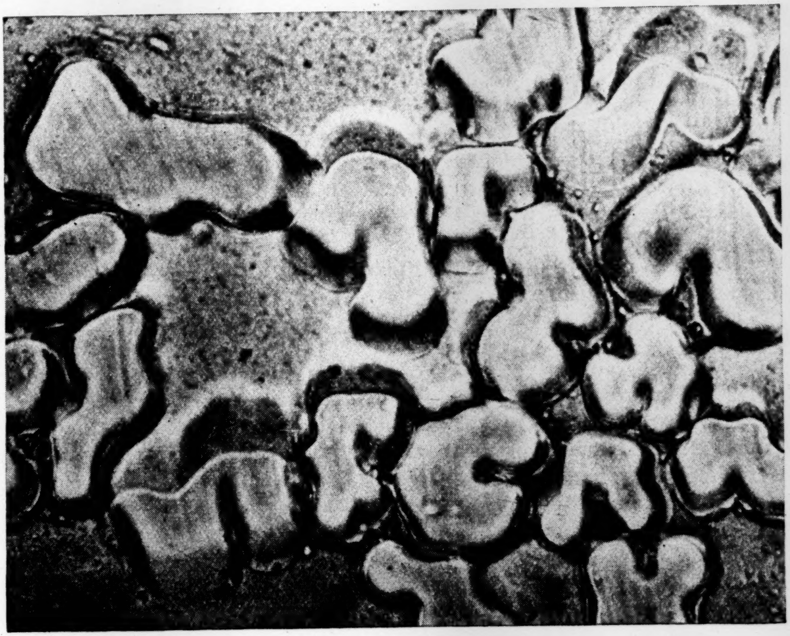

FIG. 21.—Cross-Section of Nitro-cellulose Rayon, 150 Denier (Tubize) (× 500).

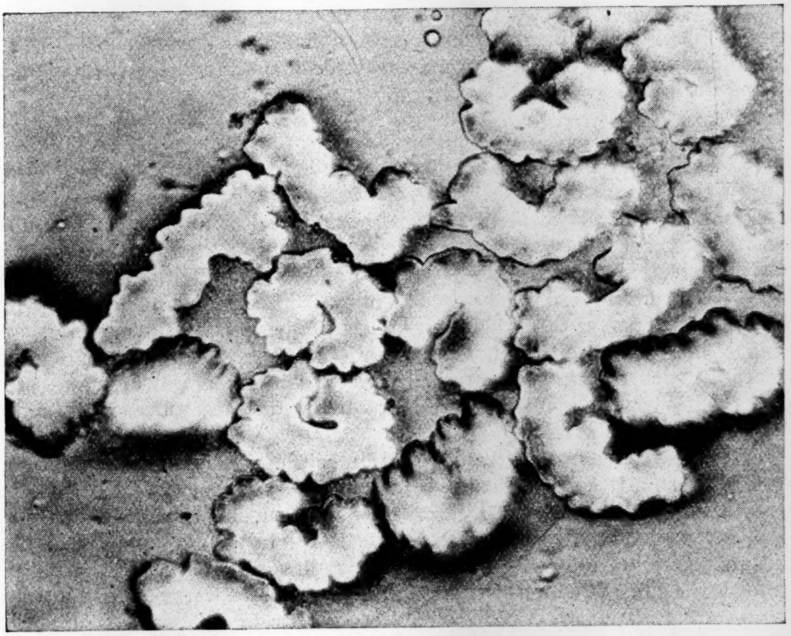

FIG. 22.—Cross-Section of Viscose Rayon, 150 Denier (Viscose Co.) (× 500).

exhibiting well-marked nodes, joints, and discolorations. There are many prominent deep longitudinal striations, crossed at irregular intervals.

Ramie is stronger than the other vegetable fibers but lacks their extensibility and flexibility.

Wool:

Wool hairs under the microscope show an outer scaly layer or cuticle and an inner fibrous layer or cortex which may or may not be pigmented, and a central canal or medulla, usually filled with more or less interrupted granular-appearing matter. The epidermal scales on the surface of the fiber can be readily discerned, even under low power magnification and these instantly distinguish the fiber from silk or vegetable fibers. The scales are more or less translucent in appearance and permit of the under cortical layer being seen through them. The nature, structure, and arrangement of the scales differ considerably with different varieties of wool. The epidermal layer of scales imparts to the wool fiber its characteristic quality of luster through the reflection of light from the surface.

The cortical layer or true fibrous portion of the fiber forms the major constituent of wool. It consists mainly of more or less elongated cells and often presents a distinctly striated appearance, the striations being visible through the translucent layers of scales. When fiber is fine in staple, the cortical cells exhibit more or less unevenness in their growth and arrangement, with the result that the fiber is contracted on one side or the other, causing the wavy appearance of such wools. Coarse wools seldom exhibit the wavy structure.

Silk:

Silk filaments after de-gumming have the appearance of a single, fine, structureless, cylindrical, transparent filament (rarely striated longitudinally), flattened in spots, and in cross-section round or irregularly oval.

The fibers are many hundreds of yards long.

Wild Silk (Tussah Silk):

Wild silk consists of flattened, ribbon-like filaments of much greater width than the mulberry silk, with many fine, longitudinal striations, and with frequent oblique depressions where the fibers have crossed one another in the cocoons. Such silks are obtained from a variety of species of silk worms other than those from which the cultivated silk (*Bombyx mori*) is obtained. The silks are usually brownish in color.

Rayons:

Viscose rayons appear to consist of ribbons scored with deep longitudinal striations. The cross-section of the filaments varies from irregular ovals to long and narrow figures which may be either straight or bent with rounded crescents. The ends of the figure are rounded, the sides are scored by notches corresponding to the longitudinal striations of the filament.

Cuprammonium (or cuprate) rayons appear as smooth rods quite uniform in diameter with sometimes fine longitudinal striations. The cross-section is oval or round.

Nitro-cellulose or collodion rayons appear as if composed of several very fine filaments which adhere to each other throughout their length. The cross-section appears as rounded figures attached to one another.

Acetate rayons appear as transparent structureless filaments with only fine striations. The cross-sections are ovals which are flattened or indented at several points or sides.

FIBER MICROSCOPY

Fiber microscopy requires a certain amount of delicate technique and skill and a knowledge of proper methods of preparing and mounting specimens for examination as well as of the proper selection of lenses. Care and skill resulting from considerable practice are required to bring out the markings and structure of the various fibers.

Microscope.—A reasonably good microscope together with a good system of first-class lenses is essential. The following table gives a suitable range of magnifications obtained from the objectives and eye-pieces noted:

	MAGNIFICATION	
OBJECTIVE	EYE-PIECE NO. 5	EYE-PIECE NO. 10
4 mm	200	400
8 mm	100	200
16 mm	50	100

It is an advantage to have the microscope fitted with a revolving nose-piece suitable for the three objectives, in which case the specimen can be readily located and viewed under different magnifications. An adjustable stage is also a convenience in locating different portions of the mount as well as in focussing. With a sub-stage diaphragm and condenser, proper conditions of illumination can be easily obtained. These are usually supplied with a good microscope.

Mounting of Specimens.—For all practical purposes and where it is not necessary to preserve the slides with their mounts, the specimens may be mounted in water. A few fibers should be well separated or teased with suitable implements and cut in convenient lengths, if necessary, after which they are laid on the slide and moistened with a drop of water. The cover-glass is placed over them and gently pressed down so as to flatten the specimen. It is usually preferable to confine the specimen to few rather than many fibers in order to avoid tangles and distortion. If permanent mounts are desired the fibers may be mounted in Canada Balsam which dries and cements the cover-glass firmly in place. Such mounting, however, is not recommended until considerable experience in fiber microscopy has been gained.

QUANTITATIVE SEPARATION OF THE MOST COMMON TEXTILE FIBERS

SELECTIVE DYEING TESTS FOR QUALITATIVE IDENTIFICATION

When little or nothing is known concerning the fibers present in a sample, it will be found desirable to first apply the following selective dyeing tests, which will indicate qualitatively the nature of the fibers present, after which more definite qualitative and finally quantitative tests may be applied.

Stripping of Sample.—If the fibers have already been dyed when received, the dye should be stripped off before making the test. This can usually be accomplished by boiling in a 3-per-cent solution of sodium hydrosulfite. After the color has been stripped, wash the material thoroughly with water to remove the stripping agent. All percentages given are based on the weight of the goods dyed.

Dyeing Tests.—Treat a piece of the sample in a solution of NaCl (3-per-cent) and Newport Direct Sky Blue FF (3-per-cent). Viscose takes a full shade of blue, while cellulose acetate is undyed.

Dye a piece of the sample at boiling for 30 minutes in a dye bath containing 1 per cent of indigo carmine and 2 per cent of acetic acid. Work the goods thoroughly while dyeing, then remove and wash well with water. Wool or silk take a full shade, while cotton and rayon are undyed.

Dye a piece of goods for 45 minutes just under boiling temperature in a bath containing 2 per cent of National Superchrome Red B (National Aniline and Chemical Co.) and 1.5 per cent of acetic acid. Then add 2 per cent of $K_2Cr_2O_7$ and boil for 30 minutes. Remove from the bath and wash thoroughly with water. Wool takes a full red shade while silk is undyed.

BURNING TEST FOR QUALITATIVE IDENTIFICATION OF VEGETABLE AND ANIMAL FIBERS

Burning Test.—The burning test may be employed as a quick means of distinguishing between vegetable and animal fibers. The vegetable fibers when ignited by a flame burn quickly and completely with the well-known odor of vegetable material; while animal fibers such as wool and silk burn more slowly with a distinct odor similar to burning glue and leave a globule of ashy matter. Silk yarn, which has been weighted with mineral salts, when ignited will not be entirely consumed and there will remain a fine mineral filament.

PROCEDURE FOR A COMPLETE QUANTITATIVE ANALYSIS

This procedure is for use in cases where an exhaustive knowledge of the several different fibers present in a sample is desired. In most cases, where not more than two different fibers are present in a sample and their identities are known qualitatively, the proper individual quantitative test may be advantageously applied directly, without first going through the general procedure.

PROCEDURE

Weigh out 2 to 5 g. of the sample in a glass-stoppered weighing bottle and dry at 100 to 110° C. to constant weight. The difference between the initial and final weights represents the moisture content. Boil the dry material thoroughly in dilute HCl (1-per-cent), care being taken not to disintegrate the fibers. If the fibers are much weakened or disintegrated, repeat with a new sample, using a weaker acid. Repeat the boiling with fresh portions of the acid until no residue is found upon evaporating a few drops of the liquid on a watch-glass. This treatment removes mineral loading matter soluble in HCl, finishing materials, more or less dyestuffs, as well as other material soluble in water.

Extract the residue first with alcohol and finally with carbon tetrachloride (CCl_4) until all soluble material is removed. Dry and weigh. Discard the extract. The residue is anhydrous fibers and any matter (mineral) not soluble in HCl. Divide immediately into two parts, and weigh each portion.

Reduce the first portion to ash. This will give the natural insoluble ash of the fibers, which is generally negligible, and any insoluble salts employed in mordanting or loading.

Heat to boiling about 60 cc. of basic $ZnCl_2$ solution, and immerse the second portion of the fibers. Remove the flame, stir the sample thoroughly for about one minute and again bring to boiling. Transfer immediately to a weighed Gooch crucible using the insoluble fibers as a mat for the crucible. Remove the insoluble fibers to a beaker containing cold, dilute HCl (5-per-cent). Thoroughly wash in the beaker by agitation and again filter. Repeat the process several times, using a weaker acid solution at each subsequent washing. Finally, remove the crucible and finish washing with several portions of hot water until free from chlorine as chloride. Dry at 100 to 105° C. and weigh.

The loss represents silk and in certain cases a portion of the sizing material. Also rayon or artificial silk is here removed.

Treat the residue with about 100 cc. of a solution of approximately 5-per-cent KOH and boil gently for 10 to 15 minutes. Pour into 500 cc. of cold water and let stand until the fibers have settled, and decant carefully the supernatant liquor, taking care to avoid loss of any fibers. Filter through a weighed Gooch crucible and wash thoroughly with boiling water. Moisten with a few cubic centimeters of dilute acetic acid and again wash with hot water, and finally with about 10 cc. of alcohol. Dry and weigh.

The loss in weight represents wool and a small portion of cotton. To correct for this add 3 per cent of the cotton to the cotton figure and subtract the same amount from the wool figure.

The residue is cotton or vegetable fibers (wood fiber, jute, linen, and similar material). Ignite. The loss represents the various vegetable fibers. The residue may consist of asbestos, mineral wool, or

other mineral fibers, and should be examined qualitatively and microscopically.

QUANTITATIVE SEPARATIONS OF SAMPLES CONTAINING TWO OR MORE KINDS OF FIBERS

In all of the test procedures described below, all weighings are made on bone-dry material and losses are calculated on the original weight. For all practical purposes, the results so obtained are sufficiently reliable. However, where strictly commercially interpretable results are desired, the procedure must be followed after first correcting the bone-dry percentages to air-dry percentages, assuming the following standard regains at normal atmosphere:

	STANDARD REGAINS AT NORMAL ATMOSPHERE, PER CENT	NORMAL REGAIN FACTOR
Wool	14.0	$\frac{100}{114} = 0.877$
Rayon	11.5	$\frac{100}{111.5} = 0.897$
Silk	11.0	$\frac{100}{111} = 0.900$
Cotton and Cellulose Acetate	6.5	$\frac{100}{106.5} = 0.939$

Example.—A sample shows by analysis on a bone-dry basis:

Cotton	30.0 per cent
Wool	45.0 " "
Silk	25.0 " "
Total	**100.0 per cent**

Divide these percentages by their respective normal regain factors and obtain values in proportion to the normal atmosphere weights of these materials:

Cotton	30.0 ÷ 0.939 = 32.0
Wool	45.0 ÷ 0.877 = 51.3
Silk	25.0 ÷ 0.900 = 27.8
Total	111.1

By multiplying by $\frac{100}{111.1}$ there is obtained a total percentage of one hundred, and the component percentages are, therefore, the proportions of each fiber present in the material, on a basis of the proper normal regains, as follows:

Cotton	$32.0 \times \frac{100}{111.1} =$	28.8 per cent
Wool	$51.3 \times \frac{100}{111.1} =$	46.2 " "
Silk	$27.8 \times \frac{100}{111.1} =$	25.0 " "
Total	=	**100.0 per cent**

DETERMINATION OF MOISTURE AND SIZE LOSSES

In all of the following quantitative separations the standard procedure for determining the moisture and size losses is as follows and will not be repeated:

Weigh out 2 to 5 g. of the sample in a glass-stoppered bottle and dry at 100 to 110° C. to constant weight. The difference between the initial and final weights represents the moisture content, calculated as a percentage of the original weight. Remove the sizing materials from the residue by boiling with HCl solution (1-per-cent). Wash out the acid with water and dry at 105° C. to get the total weight of the fibers.

COTTON AND WOOL MIXTURES

PRELIMINARY

Weigh out a piece of the goods and dye it in a bath containing 3 per cent of indigo carmine and 2 per cent of acetic acid (both percentages based on the weight of the goods). Dye at boiling temperature for about 15 minutes, washing the goods thoroughly in the bath. The cotton will take a pale blue color and the wool will dye a much deeper blue. By examining the dyed cloth under a hand glass, a good approximation of the amount of wool present may be obtained.

PROCEDURE

Remove the sizing and finishing materials by extracting in ether, boiling in distilled water for 10 minutes, treating in a hot (90 to 95° C.) solution of sodium carbonate (0.5-per-cent) for 30 minutes, rinsing in distilled water, immersing in a hot (85 to 90° C.) solution of HCl (0.5-per-cent) for 30 minutes, rinsing in distilled water, neutralizing in a solution of sodium carbonate (1-per-cent) at room temperature, rinsing thoroughly in distilled water and drying. All weighing shall be made after the specimen has been conditioned at 65 per cent relative humidity, and 70° F. Weighings shall be made to the nearest milligram or equivalent accuracy. Gently boil the specimen in at least 100 times its weight of a solution of potassium hydroxide (5-per-cent) for 10 to 15 minutes. Rinse in hot distilled water, then in a solution of acetic acid (5-per-cent) and again in distilled water. Filter, then dry in air and condition the specimen. The percentage of cotton present shall be calculated from the following formulas:

$$\text{Weight of cotton} = \frac{\text{Weight of residue}}{97} \times 100$$

$$\text{Percentage of cotton} = \frac{\text{Weight of cotton}}{\text{Original weight of specimen}} \times 100$$

COTTON, SILK, AND WOOL MIXTURES

The residue after removal of the sizing material is anhydrous fibers and any mineral matter not soluble in HCl. Divide immediately into two parts, weighing each.

Reduce the first portion to ash. This will give the natural insoluble ash of the fibers, which is generally negligible, and any insoluble salts employed in mordanting or loading.

Boil the second portion for 2 minutes in a solution of basic $ZnCl_2$ (sp. gr. 1.72), known as Elsner's reagent, which is prepared by dissolving 100 parts of $ZnCl_2$ and four parts of ZnO in 85 parts of hot water to complete solution. Wash the residue in dilute HCl and then in water until the acid has been completely removed as may be detected by litmus paper. The extract contains all the silk. The residue is cotton. Dry and weigh.

When only cotton and silk are present Method A as described under Cotton and Wool Mixtures should be used.

WOOL AND SILK MIXTURES

The residue after removal of the sizing material is anhydrous fibers and any mineral matter not soluble in HCl. Divide immediately into two parts, weighing each.

Reduce the first portion to ash. This will give the natural insoluble ash of the fibers, and any insoluble salts employed in mordanting or loading.

Dip the second portion in concentrated HCl for two minutes at 49° C. This will dissolve the silk and not materially affect the wool. Wash the residue well until all acid has been removed. Dry and weigh. The extract contains all the silk. The residue is wool.

SILK AND RAYON MIXTURES

Divide the residue after removal of sizing materials into two parts, weighing each.

Reduce the first portion to ash. This will give the natural insoluble ash of the fibers and any insoluble salts employed in mordanting or loading.

Treat the second portion at ordinary temperature for 20 minutes in an alkaline solution of copper sulfate known as Lowe's reagent, which is prepared by dissolving 10 g. of $CuSO_4 \cdot 5H_2O$ in 100 cc. of water, adding 5 cc. of glycerin and then adding a 20-per-cent caustic-soda solution until the precipitate formed redissolves. This will dissolve the natural silk, leaving the rayon as an insoluble residue. The extract contains all the silk. The residue is rayon.

ADDITIONAL TESTS FOR SILK AND RAYON MIXTURES

1. When treated with a cold semi-saturated solution of chromic acid silk is slowly soluble; all rayons except the acetate variety are soluble; while cotton and all other vegetable fibers are insoluble.

2. When treated with a 40-per-cent solution of potassium hydroxide, silk is acted upon at 65° C., dissolving at 85° C. and tussah silk swells at 75° C., dissolving at 120° C.; while rayons are insoluble on boiling.

3. In Schweitzer's reagent, silks, collodion and cellulose rayons are soluble, while gelatine rayon stains liquid-bright violet.

Schweitzer's Reagent:

Dissolve 5 g. of copper sulfate in 100 cc. of boiling water, add NaOH solution to complete precipitation; wash the precipitate thoroughly, then dissolve in the least quantity of NH_4OH. This should give a deep blue solution.

4. In Millon's Reagent a brick red color will develop with silk; while rayons remain white or uncolored.

Millon's Reagent:

Dissolve metallic mercury in its own weight of concentrated, c. p. HNO_3 (sp. gr. 1.42), then dilute this solution with an equal volume of water. Sometimes a new preparation of this reagent does not work (perhaps due to the nitric acid used), and so each lot should be tested by moistening scoured wool or real silk with it, gently warming and noting the production of a brick red color on the animal fiber. This reagent, if found reactive, should be kept in a small, tightly-stoppered bottle, when it will usually retain its staining power for a long time. It is used as a stain for animal fibers. The mixed or separated kinds of fibers are covered with a few drops of Millon's Reagent and gently warmed (not boiled).

TUSSAH SILK AND CULTIVATED MIXTURES

Divide the residue after removal of sizing materials into two parts, weighing each.

Reduce the first portion to ash. This will give the natural insoluble ash of the fibers, and any insoluble loading mordants, or tin salts.

Steep the second portion in cold concentrated HCl for 10 minutes, filter and wash the filter well with water until all acid has been removed, dry and reweigh. The extract contains all the silk. The residue is Tussah silk.

DIFFERENTIATION OF RAYONS

Samples tested by these methods shall be in the bleached or unbleached state and free from oil or other foreign substances.

TO DISTINGUISH CELLULOSE-ACETATE FROM ALL OTHER RAYONS

1. Twist fibers into a tight wad and then cautiously approach to a match flame, without being brought into contact with the flame.

Cellulose-acetate rayons melt or fuse, forming a black knob, or globule on the end, which precedes the small sputtering, relatively slow burning flame down the thread. If the flame be extinguished and the knob cooled, this will be found to be somewhat hard and resistant to crushing.

Nitro-cellulose, cuprammonium, and viscose rayons do not meltback but burn quietly and readily like bleached cotton fibers and the odor from the fumes is the same as that coming from burned cotton.

2. Treat the sample with pure acetone:

Cellulose-acetate rayon is soluble up to 1 per cent while nitrocellulose, cuprammonium, and viscose rayons are insoluble.

3. Treat the sample with glacial acetic acid (water white):

Cellulose-acetate rayon dissolves, and on adding water precipitates as a milky unstable emulsion or translucent gelatinous material.

Nitro-cellulose, cuprammonium, and viscose rayons are all insoluble.

TO DISTINGUISH NITRO-CELLULOSE RAYONS FROM VISCOSE AND CUPRAMMONIUM RAYONS

Treat the water-moistened yarn with a 1-per-cent solution of diphenylamine in concentrated H_2SO_4 (sp. gr. 1.84):

Nitro-cellulose rayon immediately assumes a blue color and dissolves in a few seconds, yielding a blue coloration.

Cuprammonium, and viscose rayons are not colored blue.

TO DISTINGUISH CUPRAMMONIUM RAYONS FROM VISCOSE RAYONS

1. Prepare a bath containing 1 per cent of the sample weight, of Pontamine Scarlet B or equivalent colors, using 0.5 g. per 200 cc. of water. Immerse samples into liquor simultaneously, heating to 65° C. for 10 minutes. The samples may then be washed thoroughly and compared wet or dry:

The cuprammonium rayons stain heavier, and the viscose rayons lighter.

2. Place 5 g. of the unknown sample of rayon (viscose or cuprammonium), together with 100 cc. of water and 3 cc. of concentrated H_2SO_4 (sp. gr. 1.84), in a flask, the mouth of which is covered with a piece of filter paper which has been saturated with a 10-per-cent solution of lead acetate; then place the flask over a moderately boiling steam bath for 4 hours. If at the end of this period the exposed part of the lead acetate paper becomes stained with a brown or black color, the rayon is viscose rayon; if no coloration is obtained the sample is cuprammonium rayon.

TENTATIVE DEFINITIONS OF TERMS RELATING TO TEXTILE MATERIALS[1]

A.S.T.M. Designation: D 123 - 30 T

This is a Tentative Standard, published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1926; REVISED, 1927, 1928, 1930.

Fabrics

Breaker Tire Fabric.—An open-woven, cotton fabric. There are three constructions, namely, (1) Plied yarns in both warp and filling; (2) Hawser cords in both warp and filling; and (3) Hawser cords in warp; singles yarn in filling.

Sheeting.—A light or medium weight plain-weave cotton fabric, woven with a single yarn from 12's to 30's.

Osnaburg.—A coarse, low count, plain-weave cotton fabric, using yarns 3's to 12's, weight 6 to 10 oz. per sq. yd., thread count approximately 30 to 38 warp and 28 to 32 filling per inch.

Airplane Fabric (Cotton).—Plain-weave cotton fabric, well woven, practically without imperfections, from mercerized yarns; width 36 to 56 in., maximum weight 4.5 oz. per sq. yd. and 80 to 84 ends and picks per inch.

NOTE.—This definition is taken from the United States Government Master Specification for Mercerized Cotton Airplane Cloth, Grade A, F. S. B. Specification No. 258a.

Awning Cloth.—Heavy cotton fabric, generally plain weave or twilled from heavy yarns, 14's to 16's warp, 10's to 16's filling.

NOTE.—Awning cloth is generally made in striped patterns, woven or printed.

Tent Duck.—A plain-weave cotton fabric from plied yarn, 2 or 3 ply warp, 2 or 3 ply filling, 28 to 30 in. wide and weighing 8 to 16 oz. per sq. yd., yarn count 46's to 64's warp, 34's to 60's filling.

NOTE.—This definition is taken from the United States Government Master Specification for Tent Duck (Special Construction for Bleaching or Dyeing, Gray), F. S. B. Specification No. 160.

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[1] Criticisms of these Tentative Definitions are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

These tentative definitions, when adopted as standard, will be added to the present Standard Definitions of Terms Relating to Textile Materials (A.S.T.M. Designation: D 123 - 30), see 1930 Book of A.S.T.M. Standards, Part II, p. 1107.

Webbing, Elastic.—A strong narrow fabric made with rubber threads as part of warp or filling or of both.

Dungaree.—A heavy cotton cloth woven in the 2/1 twill weave from dyed warp and filling yarns, woven in narrow widths, usually 28 in., approximately 68 warp by 52 filling, from 20's warp and 20's filling.

NOTE.—Dungaree is also known as "4-end twill weave."

Burlap.—A coarse, heavy, plain-weave fabric woven from coarse yarn made from jute, hemp or flax.

Felt.—A fabric of fibers united without weaving, by the application of heat, moisture and pressure or by mechanical interlacing.

Imperfections

Cockled.—A curliness or crimpiness, most marked in fine goods, appearing in fabrics when different sizes of yarn or tensions on section of the warp are accidentally introduced.

Broken Ends.—A fault caused by broken warp yarns.

Broken Picks.—A fault caused by broken or run-out filling yarn.

Yarns and Cords

Hawser Twist.—The formation of cotton twine made with the first and second twist in the same direction and the third twist in the opposite direction.

Cable Twist.—The formation of cotton twine in which each successive twist is in opposite direction to the preceding twist.

Hard Twist.—An amount of twist which is considerably more than the usual number of turns per inch contained in warp yarns.

Twine.—A cord made up of two or more yarns of medium twist with ply twist in opposite direction, for use in tying, binding, coarse sewing, etc.

Rope.—A cord made from cotton, hemp, flax, jute, etc., measuring $\frac{1}{4}$ to 5 in. in diameter.

General Definitions

Laid Fabric.—A construction in cotton fabrics made without filling yarn, the warp yarn being held together in parallel relationship in the same plane by means of rubber latex or other binding material.

Holland.—A finish, glazed or unglazed, with oil and a filling material, applied to plain-weave cotton fabrics to make them opaque or semi-opaque; resembling a beetled linen fabric formerly known as "Holland."

Book-Fold.—The fabric is doubled selvage to selvage then folded back and forth upon itself in predetermined lengths. When the piece is completed, the fold-edges on each side are folded to the center and the piece is folded once more upon itself so that the fold-edges are inside, forming a compact package as long as one-half the width of the goods.

Shoe-Fold.—The fabric is folded from both ends into twelve or sixteen folds to the piece, the length of the fold depending upon the length of the piece.

TENTATIVE SPECIFICATIONS

FOR

THERMOMETERS FOR ENGLER VISCOSIMETERS[1]

A.S.T.M. Designation: D 300 – 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

Issued, 1928; Revised, 1930.

1. These specifications cover thermometers for use in the Engler Viscosimeter graduated in Centigrade degrees, the ranges being 18 to 28° C., 39 to 54° C., and 95 to 105° C.

2. The thermometers shall conform to the following requirements:

Type: Etched stem, glass.

Liquid: Mercury.

Ranges and Subdivisions: 18 to 28° C. in 0.2° C., 39 to 54° C. in 0.2° C., and 95 to 105° C., in 0.2° C.

Total Length: 200 to 207 mm. (7.875 to 8.150 in.) for thermometers with ranges 18 to 28° C. and 95 to 105° C.
225 to 232 mm. (8.860 to 9.135 in.) for thermometers with a range of 39 to 54° C.

Stem: Plain front, enamel back, suitable thermometer tubing. Diameter 5.5 to 6.5 mm. (0.216 to 0.256 in.). The thermometer shall be mounted in a brass ferrule consisting of a tubular bushing 8 mm. (0.314 in.) in outside diameter with a flanged head approximately 12 mm. (0.47 in.) in diameter so that the upper extremity of the 8 mm. (0.314 in.) diameter is located 90 mm. (3.54 in.) from the bottom of the bulb.

Bulb: Corning normal or equally suitable thermometric glass.
Length: 13 to 19 mm. (0.510 to 0.750 in.).
Diameter: 5.5 to 6.5 mm. (0.216 to 0.256 in.).

Distance from Lowest Graduation to Bottom of Bulb: 108 to 118 mm. (4.25 to 4.65 in.).

Distance from Highest Graduation to Top of Thermometer: 30 to 40 mm. (1.18 to 1.57 in.).

Contraction Chamber: To be a long narrow type, the top to be not more than 60 mm. (2.36 in.) from the bottom of the bulb. The mercury to stand approximately in the middle of the chamber at 0° C.

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[1] Criticisms of these Tenetative Specifications are solicited and should be directed to Mr. C. S. Reeve, Secretary of Committee D-15 on Thermometers, The Barrett Co., 255 Glenwood Ave., Leonia, N. J.

EXPANSION CHAMBER: To permit heating the thermometer 50° C. above the highest temperature on the scale and in all cases to permit heating to 100° C.

FILLING ABOVE MERCURY: Nitrogen Gas.

TOP FINISH: Glass Button.

GRADUATIONS: All lines, figures and letters clear cut and distinct. The first and each succeeding 1° C. lines to be longer than the remaining lines. Graduations to be numbered each multiple of 2° C.

IMMERSION: 90 mm. (3.54 in.).

SPECIAL MARKINGS: The specific viscosity test points (25, 40, 50 and 100° C.) to be numbered with full figures. A serial number and manufacturer's name or trade mark, "90-mm. Imm.," and "ASTM Engler" to be etched on the glass stem above the metal ferrule.

SCALE ERROR: The error at any test point of the scale shall not exceed 0.1° C.

STANDARDIZATION: The thermometers are to be standardized for the condition of 90-mm. (3.54-in.) immersion.

CASE: Each thermometer shall be supplied in a suitable case on which shall appear the marking "A.S.T.M. Engler Viscosimeter Thermometer" and the range.

NOTE.—For the purpose of interpreting these specifications the following definitions apply:

The total length is the over-all length of the finished instrument.

The diameter is that measured with a ring gage.

The length of the bulb is the distance from the bottom of the bulb to the beginning of the enamel backing.

The top of the thermometer is the top of the finished instrument.

TENTATIVE RECOMMENDED PRACTICE
FOR
THERMAL ANALYSIS OF STEEL[1]
A.S.T.M. Designation: E 14 – 30 T

This **Recommended Practice** is published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1925; REVISED, 1930.

Scope.

1. Thermal analysis is the process of determining the temperature at which physical changes accompanied by an abrupt change in heat content occur in metals by observing the aberrations which the heat content changes impose on the rate of temperature change of a specimen, situated in an environment whose temperature is changing at a constant rate. The essential units required for thermal analysis are: (*a*) a furnace which may be heated and cooled at a substantially constant rate; (*b*) a temperature measuring device; and (*c*) a means for measuring time. The specific apparatus chosen depends largely on which of the several possible methods of thermal analysis is adopted with the exception that electrical resistance furnaces and potentiometric measurement of thermocouple electromotive force are in general use for the type of furnace and a temperature measuring device, respectively, and are recommended when applicable.

METHODS

Inverse-Rate and Differential Methods.

2. (*a*) The transformation data concerning steels usually required can be obtained with either the inverse-rate or differential method of thermal analysis (**1**, **2**).[2] With the inverse-rate method, the time intervals required for the temperature to change through successive equal increments are observed and plotted against the mean temperatures of the temperature increments. With the differential method, the temperature difference between the specimen and a neutral body, that is, one undergoing no abrupt change in heat content over the temperature range concerned, is plotted against the temperature of observation. With both methods it is permissible and

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[1] Criticisms of this Tentative Recommended Practice are solicited and should be directed to Mr. O. E. Harder, Secretary of Committee E-4 on Metallography, Battelle Memorial Institute, Columbus, Ohio.

[2] The boldface numbers in parentheses refer to the papers given in the list of references appended hereto.

much more convenient to plot electromotive force readings of a thermocouple instead of actual temperatures.

(*b*) Both of the methods are recommended for steel. Choice between them depends on the purposes for which they are employed. The inverse-rate method using the Rosenhain type of furnace is superior for the detection of transformation at low temperatures (100 to 500° C.) and for the study of effects of rate of temperature change. The differential method has the advantage of being easily adaptable to autographic recording and high sensitivity is possible with it (3). A machined test specimen is required in the differential method whereas with the inverse-rate method small test specimens of irregular shape may be used.

Inverse-Rate Method.

3. *Inverse-Rate Method.*—The modified type of Rosenhain furnace is recommended for obtaining inverse-rate thermal curves on steel. Details of construction can be obtained from the literature (4, 5, 6).

A specimen in the form of a disk about $\frac{1}{8}$ in. in thickness and $\frac{3}{8}$ in. in diameter mounted with the hot-junction of a thermocouple at its center and in firm metallic contact with it is recommended. The axis of the specimen should coincide with that of the tube in which it is mounted.

Time intervals may be measured most conveniently by the double stop-watch method of Merica (7). For maximum precision, chronograph measurement of time intervals is required. Curves may be plotted autographically by the recording chronograph described by French (8).

Differential Method.

4. *Differential Method.*—An electric-resistance furnace having flexible control of the rate of temperature change is recommended. The thermal insulation and heat capacity of the furnace must be reduced to a minimum to achieve this control.

The temperature of the specimen should be measured by a thermocouple, the hot-junction of which is embedded in the specimen. For the measurement of temperature differences a differential thermocouple is required. The two lead-in wires should be of the same metal and their hot terminals should be connected by a wire of different composition. One of the hot junctions should be placed in the specimen and the other in the neutral body. The electromotive force generated by temperature difference between specimen and neutral body may be measured by galvanometer deflection. Temperature differences of 0.04° C. should be detectable.

The specimen and neutral body should be thermally and geometrically similar and symmetrically placed in the furnace. The preferred form of specimen is a cylinder. The thermocouple hot-junctions need not come in metallic contact with the specimen or neutral body, but should be symmetrically placed with reference to the specimen and neutral body.

Time measurements are necessary only to establish rates of temperature change for which purpose a watch or clock with second hand suffices.

PRECAUTIONS

Precautions.

5. The use of a high-vacuum environment (less than 0.01 mm. mercury) for the specimen is desirable, but when not feasible it is recommended that precautions be taken to minimize decarbonization and convection currents. Thermocouples may be either of platinum-base or nickel-base alloys and should be of moderate size (0.020 to 0.040 in. in diameter). Their cold-junctions should be kept at 0° C., that is, in melting ice or a suitable cold-junction correction applied.

Thermocouples should be checked frequently to insure their accuracy, particularly nickel-base thermocouples used above 900° C. This may be done either by comparison with standardized couples or by the transformations in standard steel specimens. For the latter purpose, the A_2 point of ingot iron is recommended when the inverse-rate method is used and the Ac_1 point of unalloyed carbon tool steel when the differential method is used. The temperatures of these changes, taken when the rate of temperature change of the specimen is a minimum, may be taken as 768° C. and 733° C., respectively. The temperature of A_2 is practically independent of rate of temperature change, but that of Ac_1 corresponds to a rate of heating of 0.10° C. per second only.

The interpretation of thermal curves requires recognition of the fact that a peak on an inverse-rate curve does not represent the same stage of progress of the transformation as does one on a differential curve. The time ordinates of an inverse-rate curve are in effect the reciprocals of the slopes of the differential curve at corresponding temperatures and, therefore, the temperature of a minimum rate of change of heat content on a differential curve is that at which the curve has minimum slope with respect to the differential ordinate, that is, where its slope is most nearly perpendicular to the temperature ordinate. It is recommended that the interpretation and comparison of inverse-rate and differential curves be conducted on the basis outlined above.

In referring to temperatures of transformations, it is recommended that the stage of the transformation to which the temperature applies, for example, beginning, maximum or end, be always stated.

RECORDS

Records. 6. It is recommended that the following data be recorded for every thermal curve taken:

(*a*) Source and composition of steel;
(*b*) Method of thermal analysis;
(*c*) Size and mounting of specimen;
(*d*) Maximum temperature to which specimen is heated and time at that temperature;
(*e*) Previous treatment of specimen including number of times thermal curves have been taken previously on same specimen;
(*f*) The temperature of minimum rate of temperature change of the specimen at recognized and identified inflections and the direction of temperature change;
(*g*) The estimated rate of change of temperature of the furnace at the time of minimum rate of temperature change of the specimen for each inflection observed;
(*h*) The temperatures at which the beginnings and ends of inflections can be definitely recognized;
(*i*) The maximum and minimum temperatures of decalescence and recalescence in case either phenomenon is observed;
(*j*) Any departures from the foregoing recommendations.

LIST OF REFERENCES

Details of construction and operation of apparatus for obtaining thermal curves may be obtained from the following selected bibliography:

(1) Rosenhain, "Observations on Recalescence Curves," *Proceedings*, Physical Soc. London, Vol. 21, p. 180 (1908).

(2) G. K. Burgess, "On Methods of Obtaining Cooling Curves," *Scientific Paper No. 99*, U. S. Bureau of Standards, 1908.

(3) P. D. Foote, C. O. Fairchild and T. R. Harrison, "Pyrometric Practice," *Technologic Paper No. 170*, U. S. Bureau of Standards, 1921.

(4) Burgess and Crowe, "Critical Ranges A2 and A3 of Pure Iron," *Scientific Paper No. 213*, U. S. Bureau of Standards, 1913.

(5) Rosenhain, "Some Appliances for Metallographic Research," *Journal*, Inst. Metals, Vol. 13, p. 160 (1915).

(6) Scott and Freeman, "Use of a Modified Rosenhain Furnace," *Scientific Paper No. 348*, U. S. Bureau of Standards, 1919.

(7) P. D. Merica, "A Simplification of the Inverse-Rate Method for Thermal Analysis," *Scientific Paper No. 336*, U. S. Bureau of Standards, 1919.

(8) H. J. French, "A Recording Chronograph for the Inverse-Rate Method of Thermal Analysis," *Technologic Paper No. 230*, U. S. Bureau of Standards, 1923.

TENTATIVE DEFINITIONS OF TERMS RELATING TO METHODS OF TESTING[1]

A.S.T.M. Designation: E 6 - 30 T

This is a **Tentative Standard,** published for the purpose of eliciting criticism and suggestions, and as such is subject to annual revision.

ISSUED, 1923; REVISED, 1924, 1925, 1930.

Elastic Limit.—The greatest stress which a material is capable of developing without a permanent deformation remaining upon complete release of the stress.

NOTE.—In certain specifications of the Society the term "elastic limit" is used to designate a value obtained by a test method which does not involve the release of stress during a test, but which does involve the determination of a limiting load at which there occurs an appreciable change in rate of strain with respect to stress. This limit is frequently given the name "proportional limit" (or "proportional elastic limit"), and the following definition may be given:

Proportional Limit.—The greatest stress which a material is capable of developing without a deviation from the law of proportionality of stress to strain (Hooke's Law).

It is a matter of experience with many materials, especially with many metallic materials, that using ordinary methods of testing, the values found for elastic limit by means of observations of permanent deformation (set) after release of stress do not differ widely from the values found for proportional limit. Since the determination of proportional limit is much more readily made than is the determination of elastic limit it is customary to accept the proportional limit as equivalent to the elastic limit for such materials.

Using any known method, the value determined either for proportional limit or for elastic limit is somewhat arbitrary; the value depends on various test conditions, among them precision of apparatus, the scales to which stress-strain diagrams may be plotted, and the tolerance allowed before it is judged that there exists an appreciable deviation from the law of proportionality of stress to strain or an appreciable permanent deformation (set) upon release of stress.

In connection with this note on elastic limit and proportional limit, it seems proper to consider the action of a material under steadily increasing stress, and to discuss briefly five stages which may be distinguished between the first application of stress and fracture of the metal. Not all materials show all five stages, and for a material the end of one stage and the beginning of the next stage are not always marked.

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[1] **Criticisms of these Tentative Definitions are solicited and should be directed to Mr. H. F. Moore, Chairman of Subcommittee, of Committee E-1, on Mechanical Testing, University of Illinois, Urbana, Ill.**

These definitions, when adopted, will be added to the Standard Definitions of Terms Relating to Methods of Testing (A.S.T.M. Designation: E 6 - 30), see 1930 Book of A.S.T.M. Standards, Part I or Part II, pp. 932 and 1134, respectively.

These definitions are in effect a revision of the definitions of terms appearing in the former Standard Methods of Mechanical Testing of Metallic Materials (A.S.T.M Designation: E 1 - 18) which were accordingly discontinued in 1924.

In the first stage (*OA*, Fig. 1), with the use of measuring instruments of ordinary sensitiveness, deviations from the law of proportionality of stress to strain (Hooke's Law) will not be detected, nor will there be detected set after release of stress.

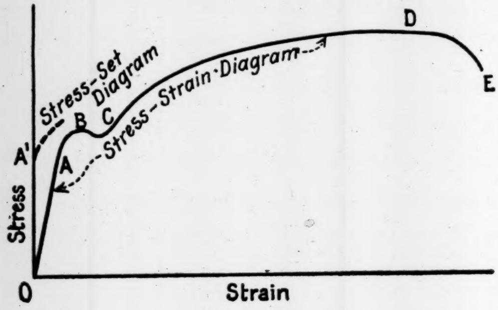

FIG. 1.

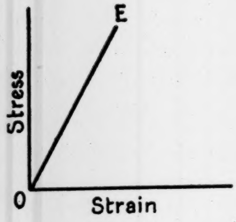

FIG. 2.

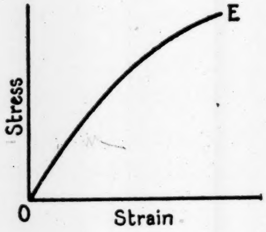

FIG. 3.

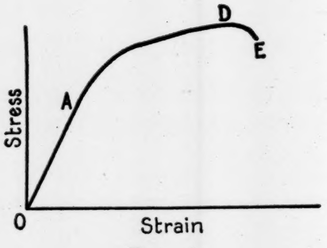

FIG. 4.

In the second stage (*AB*, Fig. 1) as stress increases there is detected an appreciable and growing deviation from the law of proportionality of stress to strain. This is usually accompanied by an appreciable and growing permanent deformation (set) after release of stress, although for some materials (*e.g.*, rubber) measurable permanent deformation may not occur after release of stress exceeding the proportional limit. Values for elastic limit and for proportional limit are found in this second stage.

The third stage (*BC*, Fig. 1) is characteristic of ductile metals. In this stage, strain increases without any increase of stress, and in some cases increase of strain is accompanied by an actual decrease of stress. The yield point is found at the beginning of this stage (at *B*, Fig. 1).

In the fourth stage (*CD*, Fig. 1) stress and strain both increase up to the maximum stress carried (*D*, Fig. 1, which gives the tensile strength in a tension test of a material).

In the fifth stage (*DE*, Fig. 1) strain increases while stress diminishes from the maximum value (*D*, Fig. 1) to fracture (*E*, Fig. 1). In considering each of these stages it is important to note that stress is computed on the basis of original cross-section of specimen.

Many materials, especially brittle materials, do not exhibit all the above-mentioned stages. Some (*e.g.*, glass and fused quartz) show only the first stage. Fig. 2 gives a representative stress-stain diagram for such materials. Some materials (*e.g.*, cast iron) show only the second stage, and Fig. 3 shows a typical stress-strain diagram for such materials. Some materials (*e.g.*, medium-hard steel) do not show the third stage, and the second stage merges into the fourth stage. Fig. 4 shows a typical stress-strain diagram for such materials. The fifth stage is absent in many materials; it is, in fact, characteristic of ductile metals only.

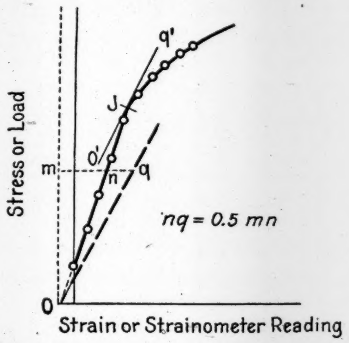

FIG. 5.—Illustrating Method II for Determining Elastic Limit.

The following methods of test are, strictly speaking, methods of determining proportional limit with various degrees of precision. However, the values determined by these methods may, for certain materials, be regarded as satisfactory and reliable values for the elastic limit, and they are therefore so used in certain specifications of the Society.

Method I. (For tension tests only, proposed by Committee A-1 on Steel, and embodied in a number of specifications for steel.) The elastic limit shall be determined by an extensometer reading to 0.0002 in. The extensometer shall be attached to the specimen at the gage marks and not to the shoulders of the specimen nor to any part of the testing machine. When the specimen is in place and the extensometer attached, the testing machine shall be operated so as to increase the load on the specimen at a uniform rate. The observer shall watch the elongation of the specimen as shown by the extensometer and shall note, for this determination, the load at which the rate of elongation shows a sudden increase. The extensometer may then be removed from the specimen and the test continued to determine the tensile strength.

Method II (proposed by the late J. B. Johnson) is a somewhat more delicate method for locating the elastic limit than is Method I. In Method II, the elastic limit shall be taken as that stress at which the rate of deformation is 50 per cent greater than the initial rate of deformation. A stress-strain diagram is necessary for determining the elastic limit by Method II. Fig. 5 illustrates the use of Method II. The initial rate of deformation is given by the ratio $mn: Om$. $nq = 0.5\ mn$, $mq = 1.5\ mn$, and the slope of Oq represents a rate of deformation 50 per cent greater than the initial rate. $O'q'$ is drawn parallel to Oq and tangent to the stress-strain diagram. The point of tangency J locates the elastic limit. In using Method II the same precautions should be observed in attaching the strainometer as for the determination of the elastic limit by Method I. Method II, if used for tension tests of metals, gives lower values for the elastic limit than does Method I. It is recommended that in using Method II for tension tests the strainometer be of such sensitiveness that it will indicate a change of strain of 0.0001 in. per inch of gage length (0.0001 mm. per millimeter of gage length) and that a corresponding degree of sensitiveness be required for strainometers used for compression tests, for flexure tests, and for torsion tests.

When it is desired to determine the elastic limit with a high degree of precision, it is suggested that the experimenter devise his own procedure, and in reporting his results describe the procedure in detail, including a statement of the limits of sensitiveness of the apparatus used and of the procedure used in plotting the stress-strain diagram from which the determination of elastic limit is made. It is to be remembered that the accurate determination of the elastic limit requires the use of accurate and sensitive instruments and the use of accurate methods of plotting test data.

Yield Point.—The stress in a material at which there occurs a marked increase in strain without an increase in stress.

NOTE.—Some metals do not show a clearly defined yield point.

Two methods are in use for determining the yield point: (I) The "drop of the beam" method, and (II) the method by use of dividers. In Method I, load is applied to the specimen at a steady rate of increase and the operator keeps the beam in balance by running out the poise at a steady rate. At the yield point the increase of load stops, but the operator, running out the poise at a steady rate, runs it a trifle beyond the balance position, and the beam of the machine drops for a brief but appreciable interval of time. In a machine fitted with a self-indicating load-measuring device there is a sudden halt of the load-indicating pointer, corresponding to the drop of the beam. The load at the "halt" or the "drop" is recorded, and the corresponding stress is taken as the yield point. This method of determining the yield point requires only one man to conduct a test.

In Method II, an observer with a pair of dividers watches for visible elongation between two section marks on the specimens. When visible stretch is observed, the load at that instant is noted, and the stress corresponding to the load is taken as the yield point. When a strainometer[1] is used in place of dividers a deformation of 0.01 in. over a gage length of 2 in. shall be regarded as indicating the yield point.

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[1] The determination of yield point with a strainometer is sometimes made in tests on non-ferrous metals.

TENTATIVE REVISIONS
OF
A.S.T.M. STANDARDS

Tentative revisions of A.S.T.M. Standards are printed for one or more years with a view of eliciting criticisms, of which the committee concerned will take due cognizance before recommending final action.

Members of the Society and others are invited to direct written criticisms of any of these Tentative Revisions to the officer of the appropriate committee, whose name and address appear in the footnote in connection with each revision.

TENTATIVE REVISIONS OF A.S.T.M. STANDARDS

A. FERROUS METALS

STANDARD SPECIFICATIONS FOR STEEL TRACK SPIKES

(A.S.T.M. Designation: A 65 - 24)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Soft Steel Track Spikes (A 65 - 26 T)"[2] is intended to replace the present standard specifications.

STANDARD SPECIFICATIONS FOR STRUCTURAL STEEL FOR SHIPS

(A.S.T.M. Designation: A 12 - 21)[1]

Section 5.—Add the following elongation requirement to the table of requirements as to tensile properties appearing after Paragraph (*a*):

Elongation in 2 in., minimum, per cent....................	22

Section 9.—Change Paragraph (*c*) from its present form: namely,

> (*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*) and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

to read as follows:

> (*c*) If the percentage of elongation of any tension test specimen is less than that specified in Section 5 (*a*), and any part of the fracture is more than $\frac{3}{4}$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

Table II.—Add a note to Table II on Permissible Overweights of Plates Ordered to Thickness, to read as follows:

> Note.—The weight of individual plates ordered to thickness shall not exceed the nominal weight by more than one and one-third the amount given in this table.

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[1] 1930 Book of A.S.T.M. Standards, Part I. **Criticisms of this revision are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Steel Co., Conshohocken, Pa.**

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 26, Part I, p. 631 (1926); also 1930 Book of A.S.T.M. Tentative Standards, p. 19.

STANDARD SPECIFICATIONS FOR ALLOY-STEEL BOLTING MATERIAL FOR HIGH-TEMPERATURE SERVICE

(A.S.T.M. DESIGNATION: A 96 – 27)[1]

Footnote.—Add the following footnote to the title of these specifications.

These specifications cover bolting stock up to and including 2½ in. in diameter.

Section 12.—Add an additional Paragraph (*c*) to read as follows:

(*c*) Specimens for tension tests shall be taken longitudinally. For sizes under 1½ in. in diameter the full section shall be turned to conform to requirements specified in Paragraph (*a*). For sizes 1½ in. and larger the specimen shall be taken half way between the center and surface.

STANDARD SPECIFICATIONS FOR HIGH-TEST GRAY-IRON CASTINGS

(A.S.T.M. DESIGNATION: A 88 – 29)[2]

Section 1.—Change from its present form: namely,

1. These specifications cover all classes of gray-iron castings which are required to have a high strength, including those generally known as semi-steel castings.

to read as follows:

1. These specifications cover all classes (Note) of gray-iron castings (free from massive cementite) which conform to the minimum physical requirements specified herein.

NOTE.—These specifications cover the so-called semi-steels, pearlitic irons, special alloy irons, and any other gray irons which conform to the requirements for physical properties.

Section 2.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

2. The tension test will be made only when specified by the purchaser and at his expense.

Section 3.—Change to read as follows by the addition of the italicized words:

3. The castings may be made by the cupola, *air-furnace*, *electric-furnace*, or any other *generally* approved process. *Where heat treatment, heated molds or other expedients are utilized for modification of the properties of the casting, the equivalent of these shall be used in the preparation of test bars.*

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[1] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. V. H. Lawrence, Secretary of Committee A-1 on Steel, Alan Wood Steel Co., Conshohocken, Pa.

[2] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. W. H. Rother, Secretary of Committee A-3 on Cast Iron, 1543 Fillmore Ave., Buffalo, N. Y.

Section 4 (a).—Change the minimum load requirement for the transverse test from "2250 lb." to "2500 lb."

Section 5.—Change to read as follows by the addition of the italicized figure and the omission of that in brackets:

> 5. When tension tests are specified, the tension test specimen shall show a minimum tensile strength of [28,000] *33,000* lb. per sq. in.

STANDARD SPECIFICATIONS FOR CHILLED CAST-IRON WHEELS

(A.S.T.M. DESIGNATION: A 46 - 24)[1]

A revision in the form of separate tentative specifications entitled "Specifications for Chilled-Tread Cast-Iron Wheels (A 46 - 30 T)"[2] is intended to replace the present standard specifications.

STANDARD METHODS OF TEST FOR MAGNETIC PROPERTIES OF IRON AND STEEL

(A.S.T.M. DESIGNATION: A 34 - 28)[3]

Section 5 (c).—Change to read as follows by the addition of the italicized figures and the omission of those in brackets:

> (*c*) For permanent magnet steel, the residual induction and coercive force shall be determined from the maximum normal induction corresponding to a magnetizing force of [200] *300* gilberts per cm. unless the maximum permeability is less than 100, in which case the maximum magnetizing force shall be not less than 2½ times the value of the magnetizing force at which this maximum permeability occurs [and shall be some multiple of 200].

B. NON-FERROUS METALS

STANDARD SPECIFICATIONS FOR BRONZE BEARING METAL IN INGOT FORM

(A.S.T.M. DESIGNATION: B 31 - 21)[4]

Section 3.—Replace the present table of requirements for chemical composition with the following:

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[1] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. W. H. Rother, Secretary of Committee A-3 on Cast Iron, 1543 Fillmore Ave., Buffalo, N. Y.

[2] See p. 976.

[3] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. R. L. Sanford, Secretary of Committee A-6 on Magnetic Properties, U. S. Bureau of Standards, Washington, D. C.

[4] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. D. K. Crampton, Secretary of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Chase Cos., Inc., Waterbury, Conn.

Alloy, Grade No.	Copper, per cent	Tin, per cent	Lead, per cent	Phosphorus, per cent	Impurities, maximum, per cent						Constituents Other than Copper, Tin, Lead and Phosphorus, per cent
					Zinc	Iron	Nickel	Antimony	Aluminum	Sulfur	
1........	85	10	5	0.70[a]	0.25	0.25	0.25	0.75	none	0.05	0.50 - 1.00
2........	80	10	10	0.70[a]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
3........	80	10	10	0.05[b]	2.00	0.25	0.25	0.75	none	0.05	2.50 - 3.00
4........	77	8	15	0.25[b]	0.50	0.25	0.25	0.75	none	0.05	0.75 - 1.25
5........	73	7	20	0.05[b]	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25
6........	70	5	25	none	0.50	0.25	0.25	0.75	none	0.05	1.00 - 1.25

[a] Minimum. [b] Maximum.

Section 4.—In the table of permissible variations for the percentage of elements specified over 10 per cent, change the permissible variations over and under the specified value from "1.50 per cent" to "2.00 per cent."

STANDARD SPECIFICATIONS FOR SEAMLESS ADMIRALTY CONDENSER TUBES AND FERRULE STOCK

(A.S.T.M. DESIGNATION: B 44 - 29)[1]

Section 14.—Change from its present form: namely,

14. The length shall not be less but may be $\frac{1}{16}$ in. more than that ordered when measured at a temperature of 20° C. (68° F.).

to read as follows:

14. The length shall not be less than that ordered when measured at a temperature of 20° C. (68° F.), but may be more than that ordered by the amounts in the following table:

ORDERED LENGTH, FT.	PERMISSIBLE TOLERANCES
Up to 15, inclusive..................................	+ $\frac{1}{16}$
Over 15 to 20, inclusive..................................	+ $\frac{3}{32}$
Over 20..................................	+ $\frac{1}{8}$

STANDARD SPECIFICATIONS FOR SEAMLESS 70-30 BRASS CONDENSER TUBES AND FERRULE STOCK

(A.S.T.M. DESIGNATION: B 55 - 25)[1]

Section 14.—Make the same change in this section as recommended in Section 14 of Specifications B 44 - 29 above.

STANDARD SPECIFICATIONS FOR SEAMLESS MUNTZ METAL CONDENSER TUBES AND FERRULE STOCK

(A.S.T.M. DESIGNATION: B 56 - 25)[1]

Section 14.—Make the same change in this section as recommended in Section 14 of Specifications B 44 - 29 above.

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[1] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. D. K. Crampton, Secretary of Committee B-5 on Copper and Copper Alloys, Cast and Wrought, Chase Cos., Inc., Waterbury, Conn.

STANDARD METHODS OF CHEMICAL ANALYSIS OF MANGANESE BRONZE

(A.S.T.M. DESIGNATION: B 27 – 19)[1]

Under the Determination of Manganese by the Persulfate Method, change the description under Method from its present form: namely,

> In a 250-cc. Erlenmeyer flask dissolve 1 g. of bronze in 24 cc. of the "solution for dissolving." Allow to stand on a steam bath or hot plate until entirely dissolved, and until the oxides of nitrogen are expelled. Add 15 cc. of $AgNO_3$ solution and 20 cc. of ammonium persulfate and leave on the steam bath until the solution has developed a full permanganate color and no bubbles can be seen to come off when the flask is given a whirling motion. Cool to below 25° C. in running water, and add 50 cc. of cold water. Titrate with standard sodium-arsenite solution to the disappearance of the pink color.

to read as follows:

> Adjust the size of sample to the expected percentage so that the portion taken does not contain more than 0.002 g. manganese. Place it in a 250-cc. Erlenmeyer flask with 24 cc. of the "solution for dissolving" and heat until solution is complete. Boil until oxides of nitrogen are expelled. Dilute to 100 cc. with boiling-hot water, add 20 cc. of $AgNO_3$ solution and 30 cc. of the persulfate solution, then remove to a moderately warm place to stand for a few minutes for complete development of the permanganic acid. Cool to below 25° C., and titrate with the standard arsenite solution to the disappearance of the pink color.

C. CEMENT, LIME, GYPSUM AND CLAY PRODUCTS

STANDARD SPECIFICATIONS FOR PORTLAND CEMENT

(A.S.T.M. DESIGNATION: C 9 – 30)[2]

A revision in the form of a separate tentative standard entitled "Specifications and Tests for Compressive Strength of Portland-Cement Mortars (C 9 – 16 T)"[3] is intended to become a part of the present standard specifications.

STANDARD SPECIFICATIONS FOR HYDRATED LIME FOR STRUCTURAL PURPOSES

(A.S.T.M. DESIGNATION: C 6 – 24)[4]

Section 12.—Change the second and fifth paragraphs from their present form: namely,

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[1] 1930 Book of A.S.T.M. Standards, Part I. Criticisms of this revision are solicited and should be directed to Mr. E. E. Thum, Secretary of Committee B-2 on Non-Ferrous Metals and Alloys, *Metal Progress*, 7016 Euclid Ave., Cleveland, Ohio.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. F. H. Jackson, Secretary of Committee C-1 on Cement, U. S. Bureau of Public Roads, Washington, D. C.

[3] *Proceedings*, Am. Soc. Testing Mats., Vol. 20, Part I, p. 599 (1920); also 1930 Book of A.S.T.M. Tentative Standards, p. 164.

[4] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. V. Brumbaugh, Secretary of Committee C-7 on Lime, 927 Fifteenth St., N. W., Washington, D. C.

The lime shall be made into a stiff putty with water and permitted to soak over night. It shall be molded in a ring such as is used with a Vicat needle, resting the specimen on a glass plate.

If the penetration is less than standard, the sample may be removed from the mold, mixed with more water, and retested. If the penetration is more than standard, the sample shall be discarded and a new one prepared.

to read respectively as follows:

The lime shall be made into a stiff putty with water, stirred vigorously with a trowel or spatula for three minutes and permitted to soak over night. It shall be stirred vigorously with a trowel or spatula for three minutes, molded in a rubber ring such as is used with a Vicat needle, resting the specimen on a glass plate.

If the penetration is less than standard, the sample may be removed from the mold, mixed with more water, stirred vigorously with a trowel or spatula for three minutes, and retested. If the penetration is more than standard, the sample shall be discarded and a new one prepared.

Section 13.—Change the first paragraph to read as follows by the addition of the italicized words:

13. Plasticity shall be determined by means of the apparatus shown in Fig. 1 as follows: Three hundred grams of the sample shall be mixed with enough water to form a thick putty *and stirred vigorously for 3 minutes with a trowel or spatula.* After aging in a vessel covered with a damp cloth for not less than 16 nor more than 24 hours, this putty shall be *stirred vigorously for 3 minutes with a trowel or spatula and* adjusted to standard consistency, as defined in Section 12, with a permissible variation of ±5 mm.

Omit the last paragraph of this section reading as follows:

After each test, the porcelain base plate shall be washed with hot water, treated with dilute hydrochloric acid to remove any lime from the surface pores, washed again with water, to remove the acid, dried by heating above 100° C., and cooled to room temperature before it is used again.

Figure 1.—Revise the constants given under the illustration of the Emley Plasticimeter by changing the first line from its present form: namely,

Absorption of porcelain base plate.—20 to 25 per cent.

to read as follows:

Absorption of porcelain base plate.—Minimum 40 g. in 24 hours. For rate of absorption of base plates, see Section 15.

Add two new sections, numbered 14 and 15, to read as follows, renumbering the present Section 14 to read Section 16:

14. *Cleaning and Care of Base Plates.*—In making plasticity determinations much of the success attainable depends upon the condition of the base plates. Continued use of the plates without proper cleaning results in clogging of the pores, with reduction in the rate of absorption. After a plate has been used

the excess lime shall be wiped off and the plate immersed in clear water for not less than two hours, after which it shall be transferred without drying to a dilute solution of hydrochloric acid (1:9) where it shall be kept immersed for another two hours. It should then be transferred to a receptacle containing running water for at least one hour. The plate is then free of acid and after the removal of excess water should be placed in an oven at a temperature of between 100 and 110° C. overnight for drying. Before using, the plate shall be cooled to room temperature.

15. *Absorption of Plasticimeter Base Plates.* (*a*) *Total Absorption.*—Plasticimeter base plates when immersed in water at room temperature for a period of 24 hours shall absorb not less than 40 g. of water. Before making the determination the plates shall be dried overnight in an oven at a temperature of between 100 and 110° C. and permitted to cool to room temperature. After immersion and before weighing, the excess water shall be wiped off with a damp cloth.

(*b*) *Rate of Absorption.*[a]—When tested over an area 2¾ in. in diameter the water absorbed shall be in accordance with the following:

	WATER ABSORBED, CC.
First Minute	8 to 14
Second Minute	5 to 7½
Third Minute	4 to 6½
Fourth Minute	4 to 6
Fifth Minute	3½ to 5½

---

[a] A convenient apparatus for determining the rate of absorption consists of a burette sealed onto an inverted glass funnel from which the stem has been removed. The diameter of the larger end of the funnel shall be ground so as to be 2¾ in. in internal diameter. The funnel may be attached to the plate on which the measurement is being made by melted paraffin. The paraffin should not be too hot. A little experience will indicate when it is of the proper consistency.

STANDARD SPECIFICATIONS FOR CEMENT-CONCRETE SEWER PIPE

(A.S.T.M. DESIGNATION: C 14 – 24)[1]

Section 1.—Add the following footnote:

Caution.—The consumer or purchaser is cautioned against using cement-concrete pipe where the sewage shows an acid reaction.

STANDARD METHOD OF TEST FOR SOFTENING POINT OF FIRE-CLAY BRICK

(A.S.T.M. DESIGNATION: C 24 – 28)[2]

Title.—Change the title of this method to read as follows, by the addition of the italicized words and the omission of those in brackets:

Standard Method of Test for [Softening Point] *Determining the Pyrometric Cone Equivalent* of Fire-Clay *and Fire* Brick.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revisions are solicited and should be directed to Mr. E. S. Rankin, Secretary of Committee C-4 on Clay and Concrete Pipe, Bureau of Sewers, City Hall, Newark, N. J.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. L. J. Trostel, Secretary of Committee C-8 on Refractories, General Refractories Co. Laboratories, Box 935, Baltimore, Md.

Section 5 (a).—In the table of heating rates change the time intervals for cones 31 to 35 to read as follows by the addition of the italicized figures and the omission of those in brackets:

Time interval to cone 31	[8] *12* minutes
" " " " 32	[4] *8* "
" " " " 33	[8] *18* "
" " " " 34	[18] *6* "
" " " " 35	[6] *10* "

STANDARD METHODS OF MAKING AND STORING COMPRESSION TEST SPECIMENS OF CONCRETE IN THE FIELD

(A.S.T.M. DESIGNATION: C 31 - 27)[1]

Section 4 (a).—Add the following sentence between the first and second sentences:

When impracticable to obtain a representative sample from the concrete after it has been placed in the work, samples shall be taken as the concrete is being delivered at the point of deposit, care being taken to obtain a sample representative of the entire batch.

Section 6.—Designate this section as Paragraph 6 (*a*) and replace the first sentence reading as follows:

Two to four hours after molding, the test specimens shall be capped with a thin layer of stiff neat-cement paste in order that the cylinder may present a smooth end for testing.

with the following two sentences:

Specimens shall not be removed from the place of molding within 24 hours and during this time shall be protected from the elements by the same method of protection as is used for the portion of the structure which the specimens represent. If steel forms are used, the specimens may be capped with a thin layer of stiff neat-cement paste from 2 to 4 hours after molding in order that the cylinder may present a smooth end for testing.

Add a new Paragraph (*b*), reading as follows:

(*b*) Where specimens are not capped in the field, they shall be capped before testing in such a manner that the ends are perfectly plane and at right angles to the axis of the cylinder. The material used for capping and the thickness of the cap shall be such that it will not flow under the load.

Sections 7 and 8.—Replace these sections, reading as follows:

7. At the end of 48 hours the test specimens shall be removed from the molds and buried in damp sand except in case the molds shown in Fig. 3 are used, when they may be buried in damp sand without removal of the mold, thus permitting shipping in the molds.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Stanton Walker, Secretary of Committee C-9 on Concrete and Concrete Aggregates, National Sand and Gravel Assn., 545 Munsey Building, Washington, D. C.

8. (*a*) The test specimens shall remain buried in damp sand until 10 days prior to the date of test. They shall then be well packed in damp sand or wet shavings and shipped to the testing laboratory, where they shall be stored either in a moist room or in damp sand until the date of test.

(*b*) Should a 7-day test be required, the test specimens shall remain at the work as long as possible to harden and then shall be shipped so as to arrive at the laboratory in time for test on the required date.

(*c*) Test specimens shall be protected from drying after removal from damp storage and before testing.

with a new Section 7 reading as follows:

7. (*a*) At the end of 24 hours, test specimens shall be removed from the place of casting and, if desired, forms may be removed. Those specimens intended for laboratory control tests shall be placed under moist curing conditions at approximately 70° F. and maintained therein until tested.

(*b*) The specimens intended for field control tests shall be kept on the structure as near the point of sampling as possible and yet receive the same protection from the elements on all surfaces and in all respects as is given to the portions of the structure which they represent. Field control specimens shall be protected from injury while on the work. For 28-day tests the specimens shall be sent to the laboratory not more than 7 days prior to the time of test. For other periods of test the specimens shall be kept in the field at least three-fourths of the test period. In any case, while in the laboratory the specimens shall be kept in ordinary air at room temperatures until tested.

STANDARD DEFINITIONS OF TERMS RELATING TO THE GYPSUM INDUSTRY

(A.S.T.M. DESIGNATION: C 11 – 28)[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to the Gypsum Industry (C 11 – 29 T)"[2] are intended to be added to the present standard definitions.

STANDARD DEFINITION OF THE TERM SAND

(A.S.T.M. DESIGNATION: C 58 – 28)[3]

The Tentative Definition of the Term Aggregate (C 58 – 28 T)[4] is intended to be included, when adopted, with the present Standard Definition of the Term Sand.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. H. J. Schweim, Secretary of Committee C-11 on Gypsum, Gypsum Assn., 211 W. Wacker Drive, Chicago, Ill.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 627 (1929); also 1930 Book of A.S.T.M. Tentative Standards, p. 175.

[3] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Ernest Ashton, Chairman of the Subcommittee on Definition of Sand and Aggregate of Committee E-8 on Nomenclature and Definitions, Lehigh Portland Cement Co., Allentown, Pa.

[4] *Proceedings*, Am. Soc. Testing Mats., Vol. 28, Part I, p. 835 (1928); also 1930 Book of A.S.T.M. Tentative Standards, p. 187.

STANDARD DEFINITIONS OF TERMS RELATING TO REFRACTORIES

(A.S.T.M. DESIGNATION: C 71 – 28)[1]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Refractories (C 71 – 30 T)"[2] are intended to be added to the present standard definitions.

D. MISCELLANEOUS MATERIALS

STANDARD SPECIFICATIONS FOR BROKEN SLAG FOR WATERBOUND BASE AND WEARING COURSE

(A.S.T.M. DESIGNATION: D 65 – 23)[3]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

4. The percentage of wear shall be not more than 12.0 per cent.

Section 6.—Change the last line of this section to read as follows by the addition of the italicized words and figures and the omission of those in brackets:

[Retained on] *Passing* 2½-in. screen . . . not [less] *more* than [85] *15* per cent.

Section 7 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

STANDARD SPECIFICATIONS FOR SHOVEL-RUN OR CRUSHER-RUN BROKEN SLAG FOR WATERBOUND BASE

(A.S.T.M. DESIGNATION: D 66 – 23)[3]

Section 4.—Omit this section, reading as follows, renumbering the subsequent sections accordingly:

4. The percentage of wear shall be not more than 15.0 per cent.

Section 6 (b).—Omit this paragraph which refers to the method for determining the percentage of wear.

STANDARD SPECIFICATIONS FOR BLOCK FOR GRANITE BLOCK PAVEMENTS

(A.S.T.M. DESIGNATION: D 59 – 26)[3]

Section 3 (a).—Change to read as follows by the addition of the italicized words:

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. L. J. Trostel, Secretary of Committee C-8 on Refractories, General Refractories Co. Laboratories, Box 935, Baltimore, Md.

[2] See p. 1037.

[3] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 801 Second Ave., New York City.

3. (*a*) The percentage of wear and the French coefficient of wear shall be determined in accordance with the Standard Method of Test for Abrasion of Rock (A.S.T.M. Designation: D 2) of the American Society for Testing Materials, ***except that the sample shall be prepared by use of a press and the fragments shall be as uniform and as nearly cubical as practicable.***

STANDARD SPECIFICATIONS FOR BLOCK FOR RECUT GRANITE BLOCK PAVEMENTS

(A.S.T.M. DESIGNATION: D 131 - 23)[1]

Section 3 (*a*).—**Make the same change as in Section 3 (*a*) of Specifications D 59 - 26 above.**

STANDARD SPECIFICATIONS FOR BLOCK FOR DURAX GRANITE PAVEMENTS

(A.S.T.M. DESIGNATION: D 132 - 23)[1]

Section 3 (*a*).—**Make the same change as in Section 3 (*a*) of Specifications D 59 - 26 above.**

STANDARD SPECIFICATIONS FOR RUBBER PUMP VALVES

(A.S.T.M. DESIGNATION: D 151 - 23)[2]

Section 4 (*c*).—Eliminate reference to reclaimed rubber.

STANDARD SPECIFICATIONS FOR TOLERANCES AND TEST METHODS FOR CERTAIN LIGHT AND MEDIUM COTTON FABRICS

(A.S.T.M. DESIGNATION: D 274 - 29)[3]

New Section.—Add the following new test procedure as Section 8:

TEAR RESISTANCE

8. (*a*) *Preferred Method.*—A specimen 3 in. in width and 8 in. in length shall be selected for test. A longitudinal cut 3 in. in length shall be made in the center of the specimen. One of the tongues thus formed shall be placed in the upper jaw of a tensile strength testing machine, preferably with automatic recording device, and the other in the lower jaw. The machine shall then be started and the specimen torn, the speed of the pulling jaw being 12 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Prévost Hubbard, Secretary of Committee D-4 on Road and Paving Materials, 801 Second Ave., New York City.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

[3] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

started shall be considered to be the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

(*b*) *Alternate Method.*—A specimen 3 in. in width and 6 in. in length shall be selected for test. An isosceles trapezoid having an altitude of 3 in. and with bases 1 in. and 4 in. in length, respectively, shall then be marked on the specimen with the aid of a template. A cut ¼ to ⅜ in. in length shall then be made in the center of the 1-in. length and perpendicular to it. The specimen shall then be clamped in the jaws of the tensile strength testing machine along the non-parallel sides of the trapezoid. The initial distance between the jaws shall be 1 in., and the width of the jaws shall be 3 in. or more. One edge of the specimen shall thus be held taut while the other edge lies in folds. The machine shall then be started and the sample torn, the speed of the pulling jaw being 3 in. per minute. The pawl on the pendulum shall be disengaged from the ratchet during the test. The average load necessary to continue the tear after it has been started shall be considered as the tear resistance of the fabric. The average of five determinations in the warp and five in the filling directions shall be reported. The capacity of the machine should be such that the specimen tears in the range of maximum sensitivity.

STANDARD GENERAL METHODS OF TESTING WOVEN TEXTILE FABRICS

(A.S.T.M. DESIGNATION: D 39 - 27)[1]

New Section.—Add as a new Section 14 the tear resistance test procedure recommended in Specifications D 274 - 29 above.

STANDARD METHODS OF SAMPLING AND ANALYSIS OF CREOSOTE OIL

(A.S.T.M. DESIGNATION: D 38 - 30)[2]

Section 4.—Change the last sentence of the first paragraph to read as follows by the addition of the italicized figure and the omission of the words and figure in brackets:

> If more than [2] *3* per cent of water is present, [or if the water is apparently present to an extent in excess of 2 per cent, but an accurate separation is impossible,] the percentage of water present shall be determined by the following method, and the water-free oil so obtained shall be used in the distillation test:

Section 9.—Replace the second and third sentences: namely,

> In case the oil requires to be brought to a higher temperature than 38° C. in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by adding 0.0008 to

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, U. S. Forest Products Laboratory, Madison, Wis.

the observed specific gravity for each degree Centigrade above 38° C. at which the test is made. This correction factor does not apply with equal accuracy to all oils, but serious error due to its use will be avoided if the foregoing precaution is observed, with respect to avoiding unnecessarily high temperature.

by a single sentence reading as follows:

In case it is necessary to bring the oil to a higher temperature than 38° C. in order to render it completely fluid, it shall be tested at the lowest temperature at which it is completely fluid, and a correction made by selecting the appropriate factor from Tables I and II shown in the Appendix.

Add as an Appendix to these methods the accompanying Tables I and II giving factors for use in correcting the volume of creosote oil from observed temperatures to 100° F. Precede the tables with the following introductory paragraph:

The accompanying Tables I and II were prepared by the U. S. Bureau of Standards to meet the demand of the users and producers of creosote oil for accurate correction factors. The tables have been adopted as standard by the American Wood Preservers' Association and are being considered for adoption by the American Railway Engineering Association; they are the outcome of a Joint Conference Committee representing these associations and the American Society for Testing Materials. Special attention is directed to the importance of the note of warning with regard to measurement of oil at temperatures below 100° F.

New Test Procedure.—The Tentative Method for the Determination of the Specific Gravity, 38°/15.5° C., of Creosote Fractions (D 38 - 30 T)[1] is intended to be included, when adopted, in the present Standard Methods of Sampling and Analysis of Creosote Oil (D 38 - 30).

STANDARD METHOD OF TEST FOR DISTILLATION OF CREOSOTE OIL

(A.S.T.M. DESIGNATION: D 246 - 30)[2]

Section 8.—Change the phrase "If the presence of water is suspected or known" to read "If the presence of 3 per cent of water is suspected or known."

Section 10.—Add a new paragraph to read as follows:

(*f*) If the fraction 0 to 210° C. contains water the amount of water shall be determined. This amount shall then be deducted from the weight of oil taken and all of the fractions shall be corrected to a percentage based on dry oil. A convenient method for determining the amount of water is to transfer this fraction, after weighing, to a tube or cylinder graduated in 0.1 cc. and add benzol. This almost always causes a clear separation between the oil and water.

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[1] See p. 1152.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. J. A. Newlin, Secretary of Committee D-7 on Timber, U. S. Forest Products Laboratory, Madison, Wis.

TABLE I.—FACTORS TO BE USED FOR CORRECTING THE SPECIFIC GRAVITY OF CREOSOTE OIL TO 100° F. WHEN THE OIL IS AT TEMPERATURES RANGING FROM 60 TO 220° F.

GROUP I.—For Distillate Creosote Including Distillate Water-Gas-Tar Creosote, Having a Specific Gravity at 100°/60° F. (37.8°/15.56° C.) Below 1.0900.

GROUP II.—For High-Boiling Distillate Creosote or Anthracene Oils Having a Specific Gravity at 100°/60° F. (37.8°/15.56° C.) Above 1.0900.

Observed Temperature, deg. Fahr.	Correction Factor to be Added to Observed Specific Gravity		Observed Temperature, deg. Fahr.	Correction Factor to be Added to Observed Specific Gravity		Observed Temperature, deg. Fahr.	Correction Factor to be Added to Observed Specific Gravity	
	Group I	Group II		Group I	Group II		Group I	Group II
220	0.0491	0.0468	180	0.0326	0.0312	140	0.0161	0.0156
219	0.0487	0.0464	179	0.0322	0.0308	139	0.0157	0.0152
218	0.0483	0.0460	178	0.0318	0.0304	138	0.0153	0.0148
217	0.0479	0.0457	177	0.0314	0.0301	137	0.0149	0.0144
216	0.0475	0.0453	176	0.0309	0.0297	136	0.0145	0.0140
215	0.0471	0.0449	175	0.0305	0.0293	135	0.0141	0.0136
214	0.0467	0.0445	174	0.0301	0.0289	134	0.0137	0.0132
213	0.0462	0.0441	173	0.0297	0.0285	133	0.0133	0.0128
212	0.0458	0.0437	172	0.0293	0.0281	132	0.0129	0.0124
211	0.0454	0.0433	171	0.0289	0.0277	131	0.0125	0.0120
210	0.0450	0.0429	170	0.0284	0.0273	130	0.0121	0.0117
209	0.0446	0.0425	169	0.0280	0.0269	129	0.0117	0.0113
208	0.0442	0.0421	168	0.0276	0.0265	128	0.0113	0.0109
207	0.0438	0.0418	167	0.0272	0.0261	127	0.0109	0.0105
206	0.0434	0.0414	166	0.0268	0.0257	126	0.0105	0.0101
205	0.0430	0.0410	165	0.0264	0.0253	125	0.0101	0.0097
204	0.0426	0.0406	164	0.0260	0.0250	124	0.0097	0.0093
203	0.0422	0.0402	163	0.0256	0.0246	123	0.0093	0.0089
202	0.0418	0.0398	162	0.0252	0.0242	122	0.0089	0.0085
201	0.0413	0.0394	161	0.0248	0.0238	121	0.0084	0.0081
200	0.0409	0.0390	160	0.0244	0.0234	120	0.0080	0.0078
199	0.0405	0.0386	159	0.0239	0.0230	119	0.0076	0.0074
198	0.0401	0.0382	158	0.0234	0.0226	118	0.0072	0.0070
197	0.0397	0.0378	157	0.0230	0.0222	117	0.0068	0.0066
196	0.0392	0.0374	156	0.0226	0.0218	116	0.0064	0.0062
195	0.0388	0.0371	155	0.0222	0.0214	115	0.0060	0.0058
194	0.0384	0.0367	154	0.0218	0.0210	114	0.0056	0.0054
193	0.0380	0.0363	153	0.0214	0.0206	113	0.0052	0.0050
192	0.0375	0.0359	152	0.0210	0.0202	112	0.0048	0.0046
191	0.0371	0.0355	151	0.0206	0.0199	111	0.0044	0.0043
190	0.0367	0.0351	150	0.0202	0.0195	110	0.0040	0.0039
189	0.0363	0.0347	149	0.0198	0.0191	109	0.0036	0.0035
188	0.0359	0.0343	148	0.0194	0.0187	108	0.0032	0.0031
187	0.0355	0.0340	147	0.0190	0.0183	107	0.0028	0.0027
186	0.0351	0.0336	146	0.0186	0.0179	106	0.0024	0.0023
185	0.0347	0.0332	145	0.0182	0.0175	105	0.0020	0.0019
184	0.0343	0.0328	144	0.0177	0.0171	104	0.0016	0.0016
183	0.0339	0.0324	143	0.0173	0.0167	103	0.0012	0.0012
182	0.0334	0.0320	142	0.0169	0.0163	102	0.0008	0.0008
181	0.0330	0.0316	141	0.0165	0.0160	101	0.0004	0.0004
						100	0.0000	0.0000

The portion of the table below should not be used unless the sample of oil has been examined and found free from crystals.

Observed Temperature, deg. Fahr.	Correction Factor to be Subtracted from Observed Specific Gravity		Observed Temperature, deg. Fahr.	Correction Factor to be Subtracted from Observed Specific Gravity		Observed Temperature, deg. Fahr.	Correction Factor to be Subtracted from Observed Specific Gravity	
	Group I	Group II		Group I	Group II		Group I	Group II
99	0.0004	0.0004	84	0.0063	0.0062	69	0.0122	0.0121
98	0.0008	0.0008	83	0.0067	0.0066	68	0.0126	0.0125
97	0.0012	0.0012	82	0.0071	0.0070	67	0.0130	0.0129
96	0.0016	0.0016	81	0.0075	0.0074	66	0.0134	0.0133
95	0.0020	0.0020	80	0.0079	0.0078	65	0.0138	0.0136
94	0.0024	0.0023	79	0.0083	0.0082	64	0.0142	0.0140
93	0.0028	0.0027	78	0.0087	0.0086	63	0.0146	0.0144
92	0.0032	0.0031	77	0.0091	0.0090	62	0.0150	0.0148
91	0.0036	0.0035	76	0.0095	0.0094	61	0.0154	0.0152
90	0.0040	0.0039	75	0.0099	0.0098	60	0.0158	0.0156
89	0.0043	0.0043	74	0.0103	0.0101			
88	0.0047	0.0047	73	0.0107	0.0105			
87	0.0051	0.0051	72	0.0111	0.0109			
86	0.0055	0.0055	71	0.0115	0.0113			
85	0.0059	0.0058	70	0.0118	0.0117			

TABLE II.—FACTORS TO BE USED FOR DETERMINING THE VOLUME OF CREOSOTE OIL AT 100° F. WHEN THE OIL IS AT TEMPERATURES RANGING FROM 60 TO 220° F.

Group I.—For Distillate Creosote Including Distillate Water-Gas-Tar Creosote, Having a Specific Gravity at 100°/60° F. (37.8°/15.56° C.) Below 1.0900.

Group II.—For High Boiling Distillate Creosote Oils Having a Specific Gravity at 100°/60° F. (37.8°/15.56° C.) Above 1.0900.

The observed volume is to be multiplied by the factor corresponding to the observed temperature.

Observed Temperature, deg. Fahr.	Volume at 100° F. Occupied by Unit Volume at Indicated Temperature		Observed Temperature, deg. Fahr.	Volume at 100° F. Occupied by Unit Volume at Indicated Temperature		Observed Temperature, deg. Fahr.	Volume at 100° F. Occupied by Unit Volume at Indicated Temperature	
	Group I	Group II		Group I	Group II		Group I	Group II
220	0.9526	0.9570	180	0.9684	0.9711	140	0.9842	0.9855
219	0.9530	0.9573	179	0.9687	0.9714	139	0.9846	0.9858
218	0.9534	0.9577	178	0.9691	0.9718	138	0.9850	0.9862
217	0.9538	0.9580	177	0.9695	0.9721	137	0.9853	0.9866
216	0.9542	0.9584	176	0.9699	0.9725	136	0.9857	0.9869
215	0.9546	0.9587	175	0.9703	0.9729	135	0.9861	0.9873
214	0.9550	0.9591	174	0.9707	0.9732	134	0.9865	0.9876
213	0.9554	0.9594	173	0.9711	0.9736	133	0.9869	0.9880
212	0.9558	0.9598	172	0.9715	0.9739	132	0.9873	0.9884
211	0.9561	0.9601	171	0.9719	0.9743	131	0.9877	0.9887
210	0.9565	0.9605	170	0.9723	0.9746	130	0.9881	0.9891
209	0.9569	0.9608	169	0.9727	0.9750	129	0.9885	0.9894
208	0.9573	0.9612	168	0.9731	0.9754	128	0.9889	0.9898
207	0.9577	0.9615	167	0 9735	0.9757	127	0.9893	0.9902
206	0.9581	0.9619	166	0.9739	0.9761	126	0.9897	0.9905
205	0.9585	0.9622	165	0.9743	0.9764	125	0.9901	0.9909
204	0.9589	0.9626	164	0.9747	0.9768	124	0.9905	0.9913
203	0.9593	0.9629	163	0.9751	0.9772	123	0.9909	0.9916
202	0.9597	0.9633	162	0.9754	0.9775	122	0.9913	0.9920
201	0.9601	0.9636	161	0.9758	0.9779	121	0.9917	0.9923
200	0.9605	0.9640	160	0.9762	0.9782	120	0.9921	0.9927
199	0.9609	0.9644	159	0.9766	0.9786	119	0.9925	0.9931
198	0.9612	0.9647	158	0.9770	0.9790	118	0.9929	0.9934
197	0.9616	0.9650	157	0.9774	0.9793	117	0.9932	0.9938
196	0.9620	0.9654	156	0.9778	0.9797	116	0.9936	0.9942
195	0.9624	0.9658	155	0.9782	0.9800	115	0.9940	0.9945
194	0.9628	0.9661	154	0.9786	0.9804	114	0.9944	0.9949
193	0.9632	0.9665	153	0.9790	0.9808	113	0.9948	0.9952
192	0.9636	0.9668	152	0.9794	0.9811	112	0.9952	0 9956
191	0.9640	0.9672	151	0.9798	0.9815	111	0.9956	0.9960
190	0.9644	0.9675	150	0.9802	0.9819	110	0.9960	0.9963
189	0.9648	0.9679	149	0.9806	0.9822	109	0.9964	0.9967
188	0.9652	0.9682	148	0.9810	0.9826	108	0.9968	0.9971
187	0.9656	0.9686	147	0.9814	0.9830	107	0.9972	0.9974
186	0.9660	0.9689	146	0.9818	0.9833	106	0.9976	0.9978
185	0.9664	0.9693	145	0.9822	0.9837	105	0.9980	0.9982
184	0.9668	0.9696	144	0.9826	0.9840	104	0.9984	0.9985
183	0.9672	0.9700	143	0.9830	0.9844	103	0.9988	0.9989
182	0.9676	0.9704	142	0.9834	0.9848	102	0.9992	0.9992
181	0.9680	0.9707	141	0.9838	0.9851	101	0.9996	0.9996
						100	1.0000	1.0000

The portion of the table below should not be used unless the sample of oil has been examined and found free from crystals.

99	1.0004	1.0004	84	1.0063	1.0057	69	1.0122	1.0111
98	1.0008	1.0007	83	1.0067	1.0061	68	1.0126	1.0115
97	1.0012	1.0011	82	1.0071	1.0065	67	1.0130	1.0118
96	1.0016	1.0014	81	1.0075	1.0068	66	1.0134	1.0122
95	1.0020	1 0018	80	1.0079	1.0072	65	1.0138	1.0126
94	1.0024	1.0022	79	1.0083	1.0075	64	1.0142	1.0129
93	1.0028	1.0025	78	1.0087	1.0079	63	1.0146	1.0133
92	1.0032	1.0029	77	1.0091	1.0083	62	1.0150	1.0136
91	1.0036	1.0032	76	1.0095	1.0086	61	1.0154	1.0140
90	1.0040	1.0036	75	1.0099	1.0090	60	1.0158	1.0144
89	1.0043	1.0040	74	1.0103	1.0093			
88	1.0047	1.0043	73	1.0107	1.0097			
87	1.0051	1.0047	72	1.0111	1.0100			
86	1.0055	1.0050	71	1.0115	1.0104			
85	1.0059	1.0054	70	1.0118	1.0108			

STANDARD METHODS OF TESTING ELECTRICAL INSULATING OILS

(A.S.T.M. DESIGNATION: D 117 - 27)[1]

1. *Scope.*—These methods are intended for oil used in transformers, oil circuit breakers and similar electrical apparatus as an insulating or cooling medium, or both.

SAMPLING

2. *General.*—Samples shall be taken and handled in such a manner that the tests made upon them indicate the characteristics of the shipment. Some tests are greatly affected by the most minute traces of impurities. This is particularly the case with the sludge test[2] and the dielectric strength test, the latter being affected by almost infinitesimal traces of moisture. If these tests are to be made it is important that the samples be handled with the utmost care to prevent such contamination. All tests are usually made on samples taken from drums. Sometimes dielectric strength tests are not made on samples taken from tank cars. Samples from tank cars are usually tested only for the physical and chemical properties that are not affected by *slight* amounts of moisture; care, however, shall be taken to prevent extraneous contamination of the samples, as contamination might affect the sludge test.[2] It is imperative, therefore, that the procedure and precautions for obtaining and transporting samples of the oil to be tested, as specified in Sections 3 to 8, inclusive, shall be observed.

APPARATUS

3. *Thiefs.* (*a*) *General.*—Thiefs shall be used for withdrawing samples of oil from drums, tank cars, or other containers of 5-gal. capacity or larger in which shipment is made. Glass or metal thiefs may be used.

(*b*) *For Drums.*—For sampling drums the thiefs shall be so designed that they will reach within approximately ⅛ in. (about 3 mm.) of the bottom and should have a capacity of approximately 1 pt. or 1 qt. (0.5 or 1 liter).

NOTE.—A convenient and simple thief for sampling 50-gal. drum containers is shown in Fig. 1, which illustrates a sheet metal thief 36 in. in length, 1¼ in. in diameter, with cone-shaped caps over the ends and having openings at the ends ⅜ in. in diameter. Three legs, equally spaced around the thief at the lower end, long enough to hold the opening ⅛ in. from the bottom of the container, aid in securing a good representative sample. Two rings soldered to opposite sides of the tube at the upper end will be found convenient for holding the thief by slipping two fingers through them, leaving the thumb free to close the opening.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of these revisions are solicited and should be directed to Mr. J. A. Scott, Secretary of Committee D-9 on Electrical Insulating Materials, General Electrical Co., Schenectady, N. Y.

This proposed revision, when accepted, will supersede Sections 1 to 7 of the present Standard Methods of Testing Electrical Insulating Oils (A.S.T.M. Designation: D 117 - 27).

[2] The great importance of a sludging test is recognized but none is included in this Standard at this time because none of the methods in general use are considered sufficiently satisfactory by Committee D-9 to warrant consideration for standardization purposes. Certain new methods are being actively investigated. See reports of Committee D-9 for 1922, 1923, 1924, 1925, 1926, 1927, 1928, 1929. For such reports see Part I of the *Proceedings* of the American Society for Testing Materials, Vols. 22 to 29, respectively. See also p. 841.

(*c*) *For Cans.*—For sampling cans of 5-gal. capacity or larger a thief, similar to that used for sampling drums but of proportionately smaller dimensions, shall be used. Cans of less than 5-gal. capacity shall be taken as a whole (see Section 7 (*e*)).

(*d*) *For Tank Cars.*—For sampling tank cars the thief shall be so designed that the sample may be obtained from within at least 0.5 in. of the bottom.

NOTE.—A thief suitable for sampling tank cars may be made from metal tubing and castings, machine-finished all over. A valve rod, whose projecting stem strikes the bottom of the car, opens the valve automatically and simultaneously releases the air through the top. Such a thief is illustrated in Fig. 2.

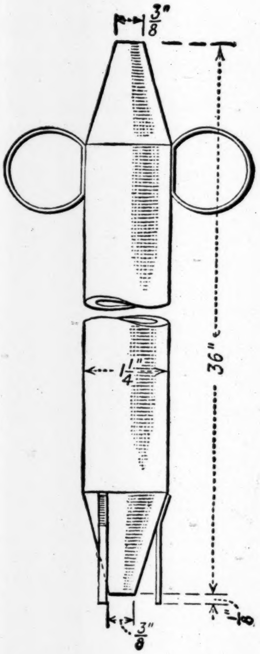

FIG. 1.—Thief for Sampling Drums.

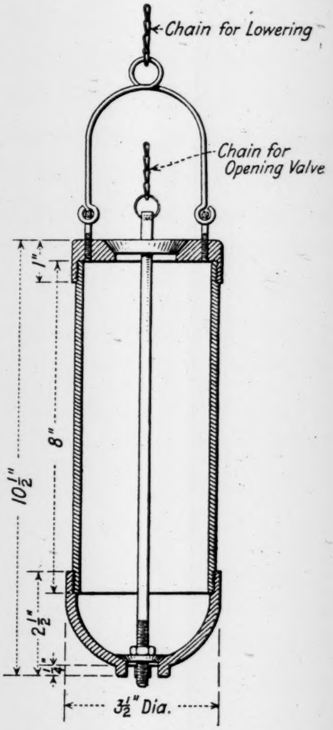

FIG. 2.—Thief for Sampling Tank Cars.

4. *Sample Containers.*—Tin cans or cork or glass-stoppered clear-glass bottles in cartons may be used as containers for the samples. The containers shall be clean and dry.

NOTE.—The clear-glass bottle offers the advantage that it may be examined to see that it is clean. It also allows visual inspection of the oil before testing, permitting the detection of free water or solid impurities. However, if samples are placed in glass bottles, they shall be kept in the dark until portions are removed for testing for color and sludge forming characteristics, as light produces changes in these properties. For this reason cardboard cartons with covers shall be provided for each bottle into which the bottle with its sample of oil shall be placed immediately after sampling. Rubber stoppers shall never be used. If cork is used it shall be of good quality with a new cork for each sample. Contact of the oil with the cork may be prevented by wrapping some tin or aluminum foil around the cork before forcing it into the mouth of the bottle. If glass-stoppered bottles are used precaution shall be taken to insure that perfectly fitting stoppers are secured. A tin can fitted with a screw cap protected with a cork disk faced with tin or aluminum will endure harder usage. If tin cans are to be employed, only those having seams soldered on the exterior surfaces shall be used.

5. *Cleaning of Apparatus.* (*a*) *General.*—All thiefs and sample containers shall be cleaned thoroughly before using, special care being taken that no lint or other fibrous material remains in or on them. Care shall be taken to insure the complete removal of all traces of soldering flux from new thiefs and new cans.

NOTE 1.—Thiefs and containers that are not chemically clean and dry are likely to contaminate the samples and cause misleading results on some of the tests.

NOTE 2.—To insure the greatest ease in removing traces of soldering flux, a flux of rosin in a suitable solvent is recommended for soldering all seams. Such a flux is easily removed with gasoline, whereas, many other fluxes are very hard to remove. Minute traces of flux may contaminate the sample so that the results obtained on dielectric strength tests and various sludge tests may be erroneous.

(*b*) *Thiefs.*—Thiefs, before using, shall be cleaned by rinsing with oil-free gasoline and dried in the hot cabinet described in Section 6 (*a*). The best procedure is to rinse them after the sampling has been finished and then place them in the hot cabinet, as in this way they will be ready for use without further cleaning when the next shipment is to be sampled.

(*c*) *Sample Containers.*—Sample containers, before using, shall be rinsed with oil-free gasoline and dried. They shall then be washed with strong soapsuds, rinsed thoroughly with distilled water and then dried by passing a current of warm air through the containers, after which they shall be immediately placed in the hot cabinet described in Section 6 (*a*). A similar washing will be sufficient for re-use of the containers that have held new oil, but those which have contained used oil shall be washed with both gasoline and benzol before being washed with soapsuds.

6. *Storage of Apparatus.* (*a*) *General.*—When not in use all thiefs and sample containers shall be kept in a hot, dry, dust-free cabinet or compartment at a temperature not less than 38° C. (100° F.).

(*b*) *Thiefs.*—Thiefs shall be kept at all times in a vertical position in the hot cabinet in a rack having a suitable drainage receptacle at the base.

(*c*) *Sample Containers.*—Containers for samples, after washing and drying as described in Section 5 (*c*), shall be kept unstoppered while in the hot cabinet but shall be closed immediately on removal. When containers must be prepared in advance and cannot be kept in the hot cabinet until approximately the time for the sample to be placed therein (as for example, when bottle containers are prepared to be sent to a distant sampling point) the same procedure of washing and drying shall be followed as described in Section 5 (*c*). In such instances, after the bottles are corked or stoppered and removed from the hot cabinet, the corks or stoppers shall be capped with paper which is tied securely on the neck, and then the capped corks or stoppers shall be sealed by dipping into melted paraffin wax so as to cover all of the paper cap and part of the neck. If this procedure is followed, care shall be taken in removing the paraffined caps preparatory to filling the bottles with samples, that no paraffin contaminates the sample.

PROCEDURE

7. *Procedure for Sampling New Oils.* (*a*) *General.*—A sufficient number of samples shall be taken to cover the requirements of the tests. It is recommended that 1 qt. of oil be taken as a sample if complete physical and chemical tests are to be made and at least 1 pt. if only the dielectric strength tests are to be made.

(*b*) Drums, tank cars, or other containers of oil shall not be sampled until the oil is at least as warm as the surrounding air, because cold oil may condense enough moisture from a humid atmosphere to affect seriously its insulating properties. Samples shall, of course, never be taken in the rain and precautions shall be taken during sampling to prevent contamination such as that which may occur from wind-blown dust or other sources.

(*c*) Samples of oil from drums and cans shall be taken only after the oil has remained undisturbed for at least eight hours.

(*d*) Drums and barrels of oil to be sampled shall be lined up, preferably on their sides with their bungs up. The bungs shall be unsealed, removed, and laid with the oily sides up beside the bung-holes. The top hole of the thief shall be closed with the thumb and the thief thrust about 1 ft. (30 cm.) into the oil. The thumb shall then be removed, allowing the oil to flow into the thief. The upper end of the thief shall again be closed with the thumb and the thief withdrawn. The oil remaining in the thief shall be used for rinsing out the thief by holding the thief nearly horizontal and turning so that the oil comes in contact with that part of the inside surface of the thief which is immersed when taking the final sample. During this rinsing of the thief, care shall be taken to avoid handling any portion of the thief that is subsequently immersed in the oil to be sampled as moisture from the fingers or hands may be sufficient to cause enough contamination of the oil to cause a low value in dielectric strength test. The oil used for rinsing shall be thrown away and the thief allowed to drain. The thief shall again be inserted into the oil but this time the thumb is not removed until the thief reaches the bottom of the container. When the thief is filled, the thumb shall be replaced, the thief quickly withdrawn and the contents allowed to flow into the sample container. The bottom hole shall not be closed with the fingers of the other hand. The free hand shall be used to guide the stream of oil by touching the thief only as necessary. The oil shall not be allowed to flow over the hand or fingers before it flows into the sample container nor shall any excess be allowed to flow over the drum or barrel and back again through the open bung-hole. When the sample container is filled it shall be closed quickly and the bung replaced in the drum and tightened. The sample container shall be labeled at once and taken to the testing laboratory as quickly as feasible.

(*e*) Smaller containers such as cans of 5-gal. capacity or larger shall be sampled with a thief, similar to the drum thief but of proportionately smaller dimensions, using a method similar in general to the one described for drums and barrels in Paragraph (*d*). To sample a shipment of cans of less capacity than 5-gal. one or more cans shall be selected at random from the shipment using the entire can (or cans) as the sample.

(*f*) Tank cars of oil shall be sampled by introducing the tank-car thief through the manhole on top of the car, the cover of which shall be removed carefully so as not to introduce any dirt into the oil. The thief shall be lowered until it strikes the bottom of the tank car when it automatically opens and fills. Under no conditions shall samples be taken from the bottom draw-off.

(*g*) When separate samples are being taken from a consignment or part of a consignment care shall be exercised to prevent contaminating the samples. A separate thief shall be used for each sample or the thief previously used shall be well drained and then thoroughly washed with oil from the next container to be sampled, throwing away the oil thus used for washing, before taking the portion reserved for the sample (see Paragraph (*d*)). Enough thiefs shall be provided to insure that each thief shall be thoroughly drained after rinsing with the oil to be sampled before it is used to withdraw the sample. For obtaining only a few samples two thiefs are enough, but for obtaining a large number of samples (for example, sampling a carload of drummed oil) six or more are desirable.

(*h*) When one average sample of a consignment or batch is being taken the same thief may be used throughout the sampling operation, omitting the precaution of rinsing the thief with oil before taking any of the portions that make up the total average sample.

8. *Procedure for Sampling Oil in Service.*—When taking samples of oil from transformers, oil circuit breakers, and similar electrical apparatus where a thief can not be used, the precautions outlined in the preceding sections shall be observed so far as practicable. In addition, care shall be taken to procure a sample that represents fairly the oil at the bottom of the tank. Transformer and oil circuit-breaker tanks and similar electrical apparatus are usually provided with drain pipes or sampling cocks from which the sample may be allowed to flow into the sample container. Before the sample is taken, enough oil shall first be allowed to flow to waste through these drain pipes or sampling cocks to insure that the sample will not be that portion which was stored in the drain pipe. For this reason, the valve and the drain pipe should be small enough to be emptied with convenience and yet large enough to give an even flow of oil and avoid clogging by sediment. A U. S. Standard ¼-in. nominal size pipe (equivalent to an inside diameter of approximately 9 mm.) with suitable valve is recommended. This, of course, may be separate from the drainage pipe and valve or may be connected to the drainage valve by means of a suitable reducer.

STANDARD METHODS OF TESTING RUBBER PRODUCTS

(A.S.T.M. DESIGNATION: D 15 - 24)[1]

A revision in the form of separate tentative methods of chemical analysis entitled "Methods of Chemical Analysis of Rubber Products (D 297 - 29 T)"[2] is intended to replace, when adopted, Sections 1 to 47 of the present standard methods.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. Arthur W. Carpenter, Secretary of Committee D-11 on Rubber Products, The B. F. Goodrich Co., Akron, Ohio.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 29, Part I, p. 795 (1929); also 1930 Book of A.S.T.M. Tentative Standards, p. 673.

STANDARD DEFINITIONS OF TERMS RELATING TO PAINT SPECIFICATIONS

(A.S.T.M. DESIGNATION: D 16 - 24)[1]

Add the following three new definitions of terms:

Screen (*Sieve*).—A plate or sheet or a woven cloth, or other device, with regularly spaced apertures of uniform size, mounted in a suitable frame or holder, for use in separating material according to size.

NOTE 1.—The shape and spacing of apertures, size of wires or threads, thickness of plate or sheet, allowable variations and similar properties should be taken care of in specifications.

NOTE 2.—In mechanical analysis testing work, when not otherwise specified, the term "sieve" shall apply to an apparatus in which the apertures are rectangular, and the term "screen" shall apply to an apparatus in which the apertures are circular.

Toughness.—That quality of a material which may be measured by the maximum impact which it will withstand without rupture.

Elasticity.—In the case of paint or varnish, that property which allows a film to follow, without rupture, changes in the extent and form of the surface to which it is applied.

STANDARD DEFINITIONS OF TERMS RELATING TO COAL AND COKE

(A.S.T.M. DESIGNATION: D 121 - 30)[2]

The Tentative Definition of the Term Coke (D 121 - 30 T)[3] is intended to be added when adopted, to the present standard definitions.

STANDARD DEFINITIONS OF TERMS RELATING TO TEXTILE MATERIALS

(A.S.T.M. DESIGNATION: D 123 - 30)[4]

Several definitions of terms published under the title "Tentative Definitions of Terms Relating to Textile Materials (D 123 - 30 T)[5]" are intended to be added, when adopted, to the present standard definitions.

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[1] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. P. H. Cathcart, Secretary of Committee D-1 on Preservative Coatings for Structural Materials, 105 York St., Brooklyn, N. Y.

[2] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. A. Selvig, Secretary of Committee D-5 on Coal and Coke, U. S. Bureau of Mines, 4800 Forbes St., Pittsburgh, Pa.

[3] See p. 1147.

[4] 1930 Book of A.S.T.M. Standards, Part II. Criticisms of this revision are solicited and should be directed to Mr. W. H. Whitcomb, Secretary of Committee D-13 on Textile Materials, Henry L. Scott Co., Providence, R. I.

[5] See p. 1254.

STANDARD DEFINITIONS OF TERMS RELATING TO METHODS OF TESTING

(A.S.T.M. DESIGNATION: E 6 – 30)[1]

The definitions of the terms "elastic limit" and "yield point" published under the title "Tentative Definitions of Terms Relating to Methods of Testing" (E 6 – 30 T)[2] are intended to be added, when adopted, to the present standard definitions.

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[1] 1930 Book of A.S.T.M. Standards, Part I or Part II. Criticisms of this revision are solicited and should be directed to Mr. H. F. Moore, Chairman of the Subcommittee on Mechanical Testing of Committee E-1 on Methods of Testing, University of Illinois, Urbana, Ill.

[2] See p. 1263.

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Chemical Compositions, Physical and Mechanical Properties and Corrosion-Resistant Properties of Corrosion-Resistant and Heat-Resistant Alloys

PLATE V.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND
HEAT-RESISTANT ALLOYS.

PART I*a*

Compositions and Physical and Mechanical Properties

Allegheny Steel Co.

Bethlehem Steel Co.

Carpenter Steel Co.

Central Alloy Steel Corp.
(Republic Steel Corp.)

Colonial Steel Co.

Crucible Steel Co. of America

Cyclops Steel Co.

Duriron Co.

Firth-Sterling Steel Co.

Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured								Types of Service for Which Recommended					Specific Gravity	Melting Range (Liquidus and Solidus Temperatures), deg. Cent.
			Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical	Typical Applications		
Allegheny Steel Co.	Allegheny Metal	C 0.20,[b] Si 0.50, Mn 0.50,[b] Cr 18.5, Ni 8.5	✓	✓	✓	✓	✓	✓	✓	...	✓	✓	✓	...	Automobiles, restaurant, dairy and building equipment used where corrosion is a serious factor	7.89	1470 to 1430
	Ascoloy 33	C 0.12,[b] Si 0.50, Mn 0.50,[b] Cr 14.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Turbine blades, valves, etc.	7.65	1495
	Ascoloy 44	C 0.20,[b] Si 0.50, Mn 1.12, Cr 25.0, Ni 17.5	✓	✓	✓	...	✓	...	...	✓	...	✓	...	...	Furnace parts, recuperators, industrial oven linings, stack dampers, pump parts, etc.	...	...
	Ascoloy 55	C 0.25,[b] Si 0.60, Mn 1.00,[b] Cr 28.0	✓	✓	✓	✓	✓	...	✓	✓	...	✓	...	...	For furnace construction where high temperatures are involved	7.6	...
	Ascoloy 66	C 0.12,[b] Si 0.43, Mn 0.40, Cr 18.5	...	✓	✓	✓	✓	✓	✓	...	✓	✓	...	...	Recommended chiefly for resistance to nitric acid	...	...
Bethlehem Steel Co.	Bethlehem Stainless Steel, Type "A"	C 0.35, Mn 0.30, Cr 14.0	...	...	✓	...	...	...	...	...	✓	...	...	...	...	7.75	1495 to 1370
Carpenter Steel Co.	Carpenter Stainless Steel No. 1	C 0.10, Cr 13.0	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Valve parts, machine parts, heat-treated parts, turbine parts	7.78	1495 to 1385
	Carpenter Stainless Steel No. 2	C 0.30, Cr 13.0	...	✓	✓	✓	✓	...	...	✓	✓	✓	✓	...	Valve parts, tapes, rules, cutlery, surgical instruments	7.75	1425
	Carpenter Stainless Steel No. 3	C 0.30, Cr 20.0, Cu 1.00	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Pump shafts, hollow balls, heat resisting parts, Diesel engine parts	7.69	1470 to 1370
	Carpenter Stainless Steel No. 4	C 0.10, Cr 18.0, Ni 9.5	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Hollow forgings, deep drawn parts, rivets, heat-resisting parts	7.71	1400
	Carpenter Stainless Steel No. 5	C 0.10, Cr 14.0, ZrS 0.40	..	✓	✓	✓	✓	...	..	✓	✓	✓	✓	...	Pump shafts, valve stems, spindles, bolts and nuts, bushings, screws, keys, golf club heads and ornamental work	7.78	1495 to 1385
Central Alloy Steel Corp. (Republic Steel Corp.)	Enduro KA 2	C 0.15,[b] Si 0.75,[b] Mn 0.50,[b] Cr 18.2, Ni 8.5	...	✓	✓	✓	✓	...	✓	✓	✓	✓	...	...	...	7.86	1405
	Enduro S	C 0.08, Si 0.50,[b] Mn 0.50,[b] Cr 13.5	...	✓	✓	✓	✓	...	...	✓	✓	✓	...	...	...	7.86	1455
	Enduro A	C 0.10,[b] Si 0.88, Mn 0.50,[b] Cr 17.5	...	✓	✓	✓	✓	...	✓	✓	✓	✓	...	...	...	7.86	1490
Colonial Steel Co.	Stainless "A"	C 0.33, Si 0.35, Cr 14.0	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	Cutlery	7.75	...
	Stainless "B"	C 0.65, Si 0.35, Cr 16.5	...	✓	✓	✓	✓	✓	...	✓	✓	...	...	...	Cutlery	7.75	...
	Stainless "I"	C 0.10,[b] Si 0.35, Cr 13.5	...	✓	✓	✓	✓	✓	...	✓	✓	...	...	...	Dairy and chemical equipment	7.86	...
	Stainless "N"	C 0.15,[b] Si 0.35, Cr 18.0, Ni 9.0	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	Dairy, paper mill and chemical equipment	7.86	...
	Stainless "U"	C 0.15,[b] Si 0.35, Cr 19.0, Ni 9.0, Mo 1.50, Cu 1.50	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	Paper mill and chemical equipment	7.86	...
Crucible Steel Co. of America	Rezistal No. 7	C 0.20,[b] Si 1.5, Cr 25.0, Ni 17.5	✓	✓	✓	...	✓	...	...	...	✓	✓	...	...	High temperature in furnace parts, retorts, hydrogenation plants, and coal distillation	7.33	...
	Rezistal KA-2	C 0.15, Cr 18.5, Ni 8.5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	Cracking still tubes, chemical plants, architectural and automobile trimmings	7.90	...
	Rezistal No. 4	C 0.20, Si 2.5, Ni 25.0, Cr 17.0	✓	✓	✓	✓	✓	...	...	...	✓	✓	✓	...	Case-hardening boxes; belt, chain and roller hearths in heat-treating furnaces	7.84	...
Cyclops Steel Co.	Cyclops No. 17 Metal	C 0.40, Si 1.00, Mn 0.75, Ni 20.0, Cr 8.0	...	✓	✓	✓	✓	✓	...	✓	✓	✓	✓	...	Valves, valve parts, turbine blading, pump rods, still plugs, thermocouple wells, miscellaneous refinery and steam applications, rotor blocks and other non-magnetic appliances	8.00	1485 to 1430
Duriron Co.	Durimet	Ni 25.0, Si 5.0, Cu 1.0, Mo 1.0[b]	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	...	Resistant to weak sulfuric acid	7.88	1340[a]
Firth-Sterling Steel Co.	Sterling Stainless Steel, Type A	C 0.35, Mn 0.35, Cr 13.5	...	✓	✓	✓	...	...	...	...	✓	...	✓	...	Cutlery, dental and surgical instruments, hardened and polished articles	7.76[c]	1510
	Sterling Stainless Steel, Type BHH	C 1.00, Mn 0.40, Cr 17.5	...	✓	✓	✓	...	...	...	✓	✓	✓	✓	...	Bearing surfaces where abrasion and corrosion are a factor.—Balls, valve stems and seats and cutlery	7.65[c]	1510
	Sterling Stainless Steel, Type MG	C 0.08, Mn 0.50, Cr 19.0	...	✓	✓	✓	...	...	...	✓	✓	✓	...	...	Golf club heads, shafting, pump rods, heat-resisting applications	7.66[c]	1510
	Sterling Stainless Steel, Type T	C 0.12, Mn 0.40, Cr 12.5	...	✓	✓	✓	...	...	...	✓	✓	...	✓	...	Golf club heads, valve parts, pump shafts, general machine parts	7.80[c]	1510 to 1400
	Sterling Nirosta	C 0.15, Cr 18.0, Ni 8.0	✓	✓	✓	✓	...	✓	...	✓	✓	✓	...	...	Sheets, tubing, cooking utensils, marine fittings, ornamental work, food containers, soda fountain trim, etc.	7.92	1510

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[a] Annealed.

[b] Maximum.

[c] Approximate.

PART I*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PR

(Liquidus and Solidus Temperatures), deg. Cent.	Physical Properties								Mechanical Properties at Room Temperature														
	Coefficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Form for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point	Compressive Proportional Limit
	Mean, 0 to 100° C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.			
to 1430	(20 to 100° C.) 0.0000173	(20 to 1000° C.) 0.0000202	0.069	(100° C.) 0.069	....	......	(25° C.) 78.0	(700° C.) 119.0	Hot rolled bars	85 000 to 120 000	30 000 to 90 000	25 000 to 75 000	70.0 to 35.0	70.0 to 55.0	28 600 000	135 to 150	....	....	....	100 to 110	....	....	...
									Cold rolled or drawn bars	157 800	153 500	......	18.0	....	......	....	....	....	....	....	....	....	...
									Plates and sheets	85 000 to 120 000	30 000 to 90 000	25 000 to 75 000	70.0 to 30.0	70.0 to 55.0	28 600 000	135 to 150	....	....	....	100 to 110	....	....	...
									Tubes	157 800	153 500	......	18.0										
									Wire	100 000 to 250 000													
1495	(20 to 100° C.) 0.0000109	(20 to 1000° C.) 0.0000136	0.096	(100° C.) 0.096	(35° C.) 0.159	(990° C.) 0.159	(25° C.) 63.6	(700° C.) 113.2	Hot rolled bars[a]	70 000	40 000	25 000	37.0	70.0	27 200 000	150	....	....	....	100	....	....	...
									Drawn	180 000	160 000	100 000	15.0	50.0	......	365	....	....	....	....	....	....	...
......	0.0000162	(20 to 1000° C.) 0.0000202	0.039	....	(35° C.) 0.142	(1000° C.) 0.142	(25° C.) 80.4	(700° C.) 117.2	Hot rolled bars	95 500 to 130 000	46 000 to 107 000	......	62.0 to 31.0	69.0 to 59.8	143 to 262	....	....	....	....	....	....	....	...
......	(20 to 100° C.) 0.0000102	(20 to 1000° C.) 0.0000134	0.059	(100° C.) 0.059	....	......	(25° C.) 72.3	(1000°C.) 118.1	Castings[e]	40 000 to 80 000	30 000 to 70 000	......	25.0	26.0	......	170 to 190	....	....	....	....	....	....	...
									Hot rolled bars[a]	75 000 to 100 000	45 000 to 60 000	......	35.0 to 25.0	65.0 to 45.0	......	160 to 200	....	....	....	....	....	....	...
......	....	....	....	....	....	......	(20° C.) 67.1	(700° C.) 116.9	Hot rolled bars[a]	65 000 to 80 000	45 000 to 55 000	......	35.0 to 25.0	60.0 min.	......	150 to 160	....	....	....	....	....	....	...
5 to 1370	0.0000101	(20 to 595° C.) 0.0000117	0.053[c]	....	....	......	....	....	Hot rolled bars[e]	95 000	65 000	......	30.0	55.0	......	179 to 196	....	....	....	....	....	....	...
5 to 1385	....	(15.0 to 815° C.) 0.0000124	....	....	0.152	......	(20° C.) 60.5	....	All forms[d]	85 000 to 180 000	60 000 to 160 000	......	77.0 to 60.0	30.0 to 15.0	......	175 to 375	5.0 to 40.0	....	....	30 to 112	....	....	...
1425	....	(15.0 to 815° C.) 0.0000126	....	....	....	......	....	....	All forms[g]	260 000	......	225 000	11.0	32.0	......	512	55.0	....	....	....	....	....	...
to 1370	....	(15.0 to 815° C.) 0.0000104	....	....	....	......	(20° C) 46.7	....	All forms[e]	100 000	68 000	50 000	22.0	55.0	......	196	14.0	....	....	....	....	....	...
400	....	(15.0 to 815° C.) 0.0000171	....	....	....	......	(20° C.) 69.3	....	All forms[e]	89 300 to 100 000	35 000 to 50 000	......	63.2 to 50.0	72.9 to 65.0	......	196 to 135	15.0	....	....	100 to 112	....	....	...
to 1385	....	(20.0 to 815° C.) 0.0000119	....	....	....	......	(20° C.) 64.8	....	All forms[d]	86 400 to 127 000	63 500 to 92 500	......	25.9 to 16.0	58.9 to 38.0	......	187 to 255	5.0 to 25.0	....	....	50 to 22	....	....	...
405	(20.0 to 315° C.) 0.0000158	(20.0 to 565° C.) 0.0000173	0.046[c]	....	0.118	......	(20.0°C.) 73.0	(800° C.) 118.0	Hot rolled bars[a]	80 000 to 100 000	35 000 to 50 000	......	55.0 min.	65.0 min.	......	150 max.	"B" 75.0 to 85.0	....	100 to 115	115 to 120	....	....	...
									Cold rolled or drawn bars	100 000 to 250 000	50 000 to 200 000	......	10.0 min.	45.0 min.	......	150 to 444	15.0 to 45.0	....	....	....	....	....	...
									Plates and sheets[a]	80 000 to 100 000	35 000 to 50 000	......	50.0 min.	....	......	....	"B" 75.0 to 85.0	....	....	....	....	......	...
1455	....	....	0.097[c]	....	0.159	......	59.8	....	Hot rolled bars[d]	75 000 to 160 000	40 000 to 135 000	......	22.0 to 14.0	60.0 to 40.0	......	150 to 340	"B" 75.0 "C" 38.0	....	80 min.	....	....	......	...
									Sheets[e]	75 000 to 95 000	42 000 to 57 000	......	22.0 min.	....	27 000 000	....	"B" 75.0 to 85.0						
1490	0.0000096	(400° C.) 0.0000101 (600° C.) 0.0000109	0.052[c]	....	....	......	....	....	Hot rolled bars[a]	70 000 to 90 000	45 000 to 65 000	......	25.0 min.	60.0 min.	......	166 to 196	....	....	....	....	....	......	...
									Cold rolled or drawn bars	85 000 to 105 000	75 000 to 95 000	......	10.0 min.	50.0 min.	......	196 to 228	....	....	....	....	....	......	...
									Plates and sheets	65 000 to 85 000	40 000 to 60 000	......	24.0 min.	....	......	....	"B" 75.0 to 85.0	....	....	....	....	......	...
.....	0.0000109	....	....	....	....	......	89.0	....	Hot rolled bars	195 500	170 500	......	10.2	32.7	30 000 000	370	....	....	....	....	....	......	...
.....	....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	...
.....	....	(500° C.) 0.0000109	0.053[c]	....	....	......	....	....	Hot rolled bars[a]	100 000	80 000	......	25.0	55.0	......	207	11.0	....	....	90	....	......	...
.....	0.000016	....	0.057	....	0.116	......	....	....	Hot rolled bars[a]	95 000	40 000	......	60.0	75.0	......	145	"B" 79.0	....	100 to 110	115 to 120	....	......	...
.....	....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	...
.....	....	....	....	....	....	......	....	....	Hot rolled bars[e]	117 000 to 136 000	57 000 to 100 000	37 000 to 80 000	40.0 to 24.0	54.0 to 39.1	......	217 to 277	....	....	49.1 to 19.3	....	....	......	...
.....	0.0000159	....	....	....	....	......	77.0	....	Hot rolled bars[e]	75 000 to 105 000	15 000 to 50 000	......	65.0 to 30.0	80.0 to 60.0	28 100 000	170 to 240	....	....	40 to 100	40 to 100+	....	......	...
									Cold rolled bars	85 000 to 90 000	35 000 to 40 000	......	30.0 to 25.0										
.....	(20 to 300° C.) 0.0000159	(300 to 600° C.) 0.0000179 (600 to 900° C.) 0.0000204	....	....	....	......	102.0	....	$\frac{1}{8}$-inch sheets[e]	109 800 to 135 000	53 300 to 113 000	37 000 to 81 000	22.5 to 17.0	....	......	207 to 286	....	....	....	....	....	......	...
o 1430	0.0000171	(20 to 600° C.) 0.0000167	0.074	....	0.07	......	86.4	....	Castings	50 000	37 500	25 000	12.5	20.0	20 000 000	146	....	22.0	....	....	....	......	...
									Forgings	125 000	80 000	63 000	27.5	54.0	28 000 000	228	19.0	34.0	37.5	70 to 75	141 600	......	91
									Hot rolled bars	125 000	80 000	63 000	27.5	54.0	28 000 000	228	19.0	34.0	37.5	70 to 75	141 600	......	91
40[e]	....	....	....	....	....	......	....	....	Hot rolled bars	100 000	45 700	......	62.0	76.4	......	160	....	....	....	99.5	....	......	...
10	....	(15 to 200° C.) 0.0000109	0.0445	....	....	......	50.0 to 70.0	....	....	150 000 to 240 000	125 000 to 200 000	100 000 to 150 000	12.0 to 4.0	40.0 to 8.0	......	325 to 500	35.0 to 52.0	47.0 to 69.0	15.0 to 6.0	25.0 to 10.0	....	......	...
10	....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	600	60.0	82	....	....	....	......	...
10	(20 to 250° C.) 0.0000099	(250 to 700° C.) 0.0000105	0.072[c]	....	0.151	......	63.1	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	...
o 1400	....	(15 to 815° C.) 0.0000124	0.096[c]	....	(35 to 990° C.)	......	65.5	....	Hot rolled bars	115 000	100 000	85 000	23.0	70.0	......	230	22.0	35.0	60.0	100	....	......	...
10	0.000017	(20 to 600° C.) 0.0000201	0.033	0.159	0.117	......	69.0	(100° C.) 90.0 (500° C.) 106.0 (800° C.) 118.0	Hot rolled bars	108 860	38 820	30 000	62.8	45.0	......	153	5.0	25.0	63.0	105	....	......	...

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[d] Properties within this range depend on section and nature of heat treatment.

[e] Properties within this range depend on section and amount of cold working

COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																		Mechanical Properties at Elevated Temperatures				
Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination
					Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.													
30 000 to 90 000	25 000 to 75 000	70.0 to 35.0	70.0 to 55.0	28 600 000	135 to 150	....	....	....	100 to 110	....	....	....	110 500	20 800	444.0	11 900 000	54 000	....	480 540 595 650 705 760 815	15 000 10 000 7 000 4 000 2 600 1 350 650	1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years	....
153 500	......	18.0	....	......	....	....	....	....	....	....	....	....	....	......	....	......	....	....				
30 000 to 90 000	25 000 to 75 000	70.0 to 30.0	70.0 to 55.0	28 600 000	135 to 150	....	....	....	100 to 110	....	....	....	110 500	20 800	444.0	11 900 000	54 000	....				
153 500	......	18.0																				
40 000	25 000	37.0	70.0	27 200 000	150	....	....	....	100	....	....	....	....	......	....	......	40 000	....	480 540 595 650 705	8 500 4 500 2 000 1 000 550	1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years	....
160 000	100 000	15.0	50.0	......	365	....	....	....	....	....	....	....	....	......	....	......	....	....				
46 000 to 107 000	......	62.0 to 31.0	69.0 to 59.8	143 to 262	....	....	....	....	....	....	....	....	....	......	....	......	....	....	815	15 000	1 per cent in 8 years	....
30 000 to 70 000	......	25.0	26.0	......	170 to 190	....	....	....	....	....	....	....	....	......	....	......	....	....	480 540 595 650 705 760	12 900 4 650 1 950 750 360 150	1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years	....
45 000 to 60 000	......	35.0 to 25.0	65.0 to 45.0	......	160 to 200	....	....	....	....	....	....	....	....	......	....	......	....	....				
45 000 to 55 000	......	35.0 to 25.0	60.0 min.	......	150 to 160	....	....	....	....	....	....	....	....	......	....	......	....	....	540 595 650 705 760	4 200 1 950 900 525 225	1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years 1 per cent in 8 years	....
65 000	......	30.0	55.0	......	179 to 196	....	....	....	....	....	....	....	....	......	....	......	....	....	....	....	....	....
60 000 to 160 000	......	77.0 to 60.0	30.0 to 15.0	......	175 to 375	5.0 to 40.0	....	....	30 to 112	....	....	....	....	......	....	......	....	....	....	....	....	....
......	225 000	11.0	32.0	......	512	55.0	....	....	....	....	....	....	....	......	....	......	....	...	....	....	....	....
68 000	50 000	22.0	55.0	......	196	14.0	....	....	....	....	....	....	....	......	....	......	....	....	205 315 425 540	28 000 22 000 9 000 4 000	None	Long time tests
35 000 to 50 000	......	63.2 to 50.0	72.9 to 65.0	......	196 to 135	15.0	....	....	100 to 112	....	....	....	....	......	....	......	....	....	....	....	....	....
63 500 to 92 500	......	25.9 to 16.0	58.9 to 38.0	......	187 to 255	5.0 to 25.0	....	....	50 to 22	....	....	....	....	......	....	......	....	....	....	....	....	....
35 000 to 50 000	......	55.0 min.	65.0 min.	......	150 max.	"B" 75.0 to 85.0	....	100 to 115	115 to 120	....	....	....	....	......	....	......	....	....	540 595 650 815 	15 000 17 000 8 000 9 500 5 500 7 000 750 800	1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours	Long time tests
50 000 to 200 000	......	10.0 min.	45.0 min.	......	150 to 444	15.0 to 45.0	....	....	....	....	....	....	....	......	....	......	....	....				
35 000 to 50 000	......	50.0 min.	....	......	....	"B" 75.0 to 85.0	....	....	....	....	....	....	....	......	....	......	....	....				
40 000 to 135 000	......	22.0 to 14.0	60.0 to 40.0	......	150 to 340	"B" 75.0 "C" 38.0	....	80 min.	....	....	......	....	....	......	....	......	....	....	540 595 650 	10 000 13 000 4 000 5 200 1 600 2 100	1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours	Long time tests
42 000 to 57 000	......	22.0 min.	....	27 000 000	....	"B" 75.0 to 85.0																
45 000 to 65 000	......	25.0 min.	60.0 min.	......	166 to 196	....	....	....	....	....	......	....	....	......	....	......	....	....	540 595 650 735 	7 000 8 500 4 500 5 200 1 600 2 100 900 1 200	1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours 1 per cent in 100 000 hours 1 per cent in 10 000 hours	....
75 000 to 95 000	......	10.0 min.	50.0 min.	......	196 to 228	....	....	....	....	....	......	....	....	......	....	......	....	....				
40 000 to 60 000	......	24.0 min.	....	......	....	"B" 75.0 to 85.0	....	....	....	....	......	....	....	......	....	......	....	....				
170 500	......	10.2	32.7	30 000 000	370	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
80 000	......	25.0	55.0	......	207	11.0	....	....	90	....	......	....	....	......	....	......	....	....	....	....	....	....
40 000	......	60.0	75.0	......	145	"B" 79.0	....	100 to 110	115 to 120	....	......	....	....	......	....	......	....	....	540 595 650 760	15 000 8 000 4 500 2 000	....	....
......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
57 000 to 100 000	37 000 to 80 000	40.0 to 24.0	54.0 to 39.1	......	217 to 277	....	....	49.1 to 19.3	....	....	......	....	....	......	....	......	....	....	....	....	....	....
15 000 to 50 000	......	65.0 to 30.0	80.0 to 60.0	28 100 000	170 to 240	....	....	40 to 100	40 to 100+	....	......	....	....	......	....	......	....	....	....	....	....	....
35 000 to 40 000	......	30.0 to 25.0																				
53 300 to 113 000	37 000 to 81 000	22.5 to 17.0	....	......	207 to 286	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
37 500	25 000	12.5	20.0	20 000 000	146	....	22.0	....	....	....	......	....	....	......	....	......	....	....	540 595 650 705	20 500 11 800 5 600 4 000	1 per cent in 10 000 hours 1 per cent in 10 000 hours 1 per cent in 10 000 hours 1 per cent in 10 000 hours	Long time tests
80 000	63 000	27.5	54 0	28 000 000	228	19.0	34.0	37.5	70 to 75	141 600	......	91 000	137 000	......	....	......	55 000					
80 000	63 000	27.5	54.0	28 000 000	228	19.0	34.0	37.5	70 to 75	141 600	......	91 000	137 000	......	....	......	55 000					
45 700	......	62 0	76.4	......	160	....	....	....	99.5	....	......	....	....	......	....	......	....	....	....	....	....	....
125 000 to 200 000	100 000 to 150 000	12.0 to 4.0	40.0 to 8.0	......	325 to 500	35.0 to 52.0	47.0 to 69.0	15.0 to 6.0	25.0 to 10.0	....	......	....	....	......	....	......	....	....	....	....	....	....
......	......	....	....	......	600	60.0	82	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
100 000	85 000	23.0	70.0	......	230	22.0	35.0	60.0	100	....	......	....	....	......	....	......	....	....	....	....	....	....
38 820	30 000	62.8	45.0	......	153	5.0	25.0	63.0	105	....	......	....	100 800	21 280 (yield point)	257.0	......	39 000	....	540 595 650 705 760 815	15 200 8 500 5 400 3 400 1 900 900	1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests

[e] Properties within this range depend on section and amount of cold working

[f] Subject to grain growth in welding. Use Enduro KA2 analysis whe

PLATE V.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.
PART I*a*.

	Fabricating Properties															
d of ss nation	Machining	Hot Working		Cold Working	Welding					Brazing	Soldering	Precautions to be Observed			Trade Name of Alloy	Manufacturer
		Optimum Temperature Range, deg. Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance			In Design	In Fabricating	In Use		
.....	Tough, requires slow speed and feed	1150 to 925	....	......	..	✓	✓	✓	✓	✓	✓	High coefficient of expansion should be considered	Preheat from 95 to 425° C. before welding. Should be annealed above 925° C. and air cooled when practicable	Recommend annealing all parts above 925° C. and air cooling all parts that have been cold worked or worked hot below 900° C.	Allegheny Metal........	Allegheny Steel Co.
.....	About the same as 0.45 per cent carbon steel	1150 to 925	....	......	..	✓	✓	✓	✓	✓	✓	....	Welds should be annealed at 790° C. and air cooled	....	Ascoloy 33..............	
.....	Tough, require slow speed and feed	1150 to 925	....	......	..	✓	✓	✓	✓	✓	✓	High coefficient of expansion should be considered	Preheat from 95 to 425° C. before welding. Annealed wherever practical above 925° C. Air cooled	Recommend annealing at 925° C. parts worked cold or worked hot below 900° C. Air cooled	Ascoloy 44..............	
.....	About the same as 0.45 per cent carbon steel	1095 to 870	....	......	..	✓	✓	✓	✓	✓	✓	....	....	Will become brittle if used or slowly cooled between 400 and 600° C.	Ascoloy 55..............	
....	About the same as 0.45 per cent carbon steel	1150 to 870	....	......	✓	✓	✓	✓	✓	✓	✓	....	....	....	Ascoloy 66..............	
....	Use half speed of machine steel, $\frac{1}{8}$ to $\frac{3}{16}$ in. depth of cut and 0.20 in. feed	1035 to 980	Can be forged to 870° C.	......	..	..	..	..	..	✓	✓	....	....	....	Bethlehem Stainless Steel Type "A"	Bethlehem Steel Co.
....	Good	....	....	......	✓	✓	✓	✓	..	✓	✓	....	....	....	Carpenter Stainless Steel No. 1	Carpenter Steel Co.
....	Good	....	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Carpenter Stainless Steel No. 2	
tests	Good	....	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Carpenter Stainless Steel No. 3	
....	Fair	....	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Carpenter Stainless Steel No. 4	
....	Excellent, same as Bessemer screw stock	....	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Carpenter Stainless Steel No. 5	
tests	Machineable	1175	Do not forge below 980° C.	......	✓	..	✓	✓	✓	✓	✓	Should not be welded to steel; difference in coefficient of expansion	Rivets should be driven cold or between 980 and 1175° C.	....	Enduro KA 2...........	Central Alloy Steel Corp (Republic Steel Corp.)
tests	Compares to 0.45 per cent carbon steel	1150 to 955	Forges similar to 0.40 per cent carbon steel	......	..	✓	..	✓	✓	✓	✓	Should be annealed after welding	Must be annealed	Polish to obtain stainless qualities	Enduro S...............	
...	Good, same as 0.40 per cent carbon steel	1095 to 1035	Finishing temperature under 870° C.	......	✓	✓	..	✓	✓	✓	✓	Riveted construction preferred to welded construction	Do not heat above 840° C. when bending or flanging. Do not heat rivets above 840° C.	Should not be in temperature range of 480 to 650° C. without heating to 785° C. before cooling to room temperature	Enduro A...............	
...	With some difficulty	925 to 1150	....	......	..	✓	..	..	..	✓	..	....	....	....	Stainless "A"..........	Colonial Steel Co.
...	With some difficulty	925 to 1035	....	......	..	✓	..	✓	..	✓	..	....	....	....	Stainless "B"..........	
...	With some difficulty	925 to 1175	....	......	..	✓	..	✓	..	✓	✓	....	....	....	Stainless "I"..........	
...	Difficult to machine	1035 to 1205	....	......	..	✓	..	✓	..	✓	✓	....	....	....	Stainless "N"..........	
...	Difficult to machine	1035 to 1205	....	......	..	✓	..	✓	..	✓	✓	....	....	....	Stainless "U"..........	
...	Rather hard	1150 to 900	....	......	..	✓	..	✓	..	✓	✓	....	....	....	Rezistal No. 7..........	Crucible Steel Co. of America
...	Fair	1150 to 900	Finish above 900° C.	......	..	✓	..	✓	..	✓	✓	....	....	....	Rezistal KA-2...........	
...	Fair	1150 to 900	....	......	..	✓	..	✓	..	✓	✓	....	....	....	Rezistal No. 4..........	
ests	Reduce speed and feed	1010 to 1120	Preheat 870 to 925° C.	......	..	✓	..	✓	✓	✓	✓	....	....	....	Cyclops No. 17 Metal....	Cyclops Steel Co.
...	Not difficult	1065	....	......	..	✓	..	✓	✓	..	✓	....	Relieve stresses by heating to 1065° C. Air quenched	....	Durimet................	Duriron Co.
...	Machines readily in partially softened state	925 to 1095	Air hardening steel	......	..	✓	..	✓	✓	✓	..	....	....	....	Sterling Stainless Steel, Type A	Firth-Sterling Steel Co.
...	....	925 to 1010	Austenitic with high and prolonged heating	......	..	✓	..	✓	✓	✓	✓	....	....	....	Sterling Stainless Steel, Type BHH	
..	Gummy	870 to 1095	Forges very readily	......	..	✓	..	✓	✓	..	✓	....	....	....	Sterling Stainless Steel, Type MG	
..	Machines readily	925 to 1095	Air hardening steel	......	..	✓	..	✓	✓	✓	✓	....	Must be annealed before machining	....	Sterling Stainless Steel, Type T	
sts	Somewhat difficult. Use of lubricant and extra tool clearance	955 to 1285	Forges readily	......	..	✓	..	✓	✓	✓	✓	....	Must be fully austenitic before cold working	....	Sterling Nirosta........	

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ysis where possible.

[g] Hardened.

[e] Liquidus.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART I*b*

Corrosion-Resistant Properties

- Allegheny Steel Co.
- Bethlehem Steel Co.
- Central Alloy Steel Corp. (Republic Steel Corp.)
- Colonial Steel Co.
- Crucible Steel Co. of America
- Cyclops Steel Co.
- Duriron Co.
- Firth-Sterling Steel Co.

R=Recommended.

N=Not recommended.

V=Varies with individual conditions; consult manufacturer

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																						
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydrocarbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen		Chlorine		Hydr Aci
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for
Allegheny Steel Co.	Allegheny Metal	925	....	925	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	....	....	[a]	....	....	....	....
	Ascoloy 33	815	....	815	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	....	....	[a]	....	....	....	....
	Ascoloy 44	1150	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	....	....	[a]	....	....	....	....
	Ascoloy 55	1175	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	....	....	[a]	....	....	....	....
	Ascoloy 66	900	....	900	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	[a]	....	....	....	[a]	....	....	....	....
Bethlehem Steel Co.	Bethlehem Stainless Steel, Type "A"	540	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Central Alloy Steel Corp. (Republic Steel Corp.)	Enduro KA 2	870	....	870	....	870	....	870	....	870	....	870	....	540	....	540	....	540	....	870	....	....	....	....
	Enduro S	760	....	760	....	760	....	760	....	760	....	760	....	760	....	760	....	760	....	760	....	....	....	....
	Enduro A	870	....	870	....	870	....	870	....	870	....	870	....	870	....	815	....	815	....	870	....	....	....	....
Colonial Steel Co.	Stainless "A"	815	....	....	....	840	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Stainless "B"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Stainless "I"	815	....	815	....	900	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Stainless "N"	900	....	900	....	980	....	1205	....	980	....	815	....	....	....	....	....	....	....	815	....	....	....	....
	Stainless "U"	900	....	900	....	980	....	1205	....	980	....	815	....	....	....	....	....	....	....	815	....	....	....	....
Crucible Steel Co. of America	Rezistal No. 7	1095 to 1150	....	1095 to 1150	....	1095 to 1150	....	1095 to 1150	....	1095 to 1150	....	1095 to 1150	....	1095 to 1150	....	180	....	....	....	....	....	....	....	....
	Rezistal KA-2	925	....	870	....	870	....	760	....	870	....	705	....	705	....	150	....	....	....	....	....	....	....	....
	Rezistal No. 4	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	....	....	....	....	....	....	....	....	....	....	....
Cyclops Steel Co.	Cyclops No. 17 Metal	760	....	760	....	760	....	760	....	760	....	760	....	760	....	760	....	....	....	....	....	....	....	....
Duriron Co.	Durimet	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Firth-Sterling Steel Co.	Sterling Stainless Steel, Type A	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Sterling Stainless Steel, Type BHH	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Sterling Stainless Steel, Type MG	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Sterling Stainless Steel, Type T	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Sterling Nirosta	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

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[a] Consult manufacturer.

[b] Hydrogen and nitrogen only.

ufacturer.

PART I*b*. CORROSION-RESISTANT PROPERTIE

	Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia		Fused Caustic Alkalis		Fused Chlorides		Form of Material	Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium a Magnesiu Brines	
lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.		Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute
.	....	....	[a]	....	[a]	....	....	....	....	20	V	V	V	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R
										100	N	N	N	100	R	R	R	100	N	N	N	100	V	V	V	100	R	R	R	100	R	R	R	100	V	V	V	100	V
														Boiling			V																						
.	....	....	[a]	....	[a]	....	....	....	....	20	N	N	N	20	V	V	V	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V
										100	N	N	N	100	V	V	V	100	N	N	N	100	V	V	V	100	V	V	V	100	R	R	R	100	V	V	V	100	V
										Boiling			N	Boiling			N																						
.	....	....	[a]	....	[a]	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V
										100	N	N	N	100	V	V	V	100	N	N	N	100	V	V	V	100	R	R	R	100	R	R	R	100	R	R	R	100	V
														Boiling			V									Boiling			V										
.	....	....	[a]	....	....	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	V	V	V	20	R	R	R	20	R	R	R	20	V	V	V	20	V
										100	N	N	N	100	V	V	V	100	N	N	N	100	N	N	N	100	V	V	V	100	R	R	R	100	V	V	V	100	V
.	....	....	[a]	....	[a]	....	....	....	....	20	N	N	V	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V
										100	N	N	N	100	R	R	R	100	N	N	N	100	V	V	V	100	R	R	R	100	R	R	R	100	V	V	V	100	V
										Boiling			N	Boiling			RV																						
	....	....	....	....	....	....	....	....	....	20	N	N	V	20	R	R	R	20	N	N	N	20	V	V	V	20	5 per cent R	V	V	20	R	R	V	20	R	R	R	...	..
	....	....	870[b]	....	....	....	....	....	....	20	N	N	R	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	..
										70	N	N	N	70	R	R	R	70	N	N	N	70	R	R	R	70	R	R	R	70	R	R	R	...	..	..	..	...	..
										Boiling	N	N	N	Boiling	R	R	N	Boiling	N	N	N	Boiling	R	R	R	Boiling	R	R	R	Boiling	R	R	R	...	..	..	..	...	..
	....	....	760	....	....	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	..
										70	N	N	N	70	R	R	R	70	N	N	N	70	R	R	R	70	R	R	R	70	R	R	R	...	..	..	..	...	..
										Boiling	N	N	N	Boiling	R	R	N	Boiling	N	N	N	Boiling	R	R	N	Boiling	R	R	R	Boiling	R	R	R	...	..	..	..	...	..
	....	....	870[b]	....	....	....	....	....	....	20	N	N	R	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	..
										70	N	N	R	70	R	R	R	70	N	N	N	70	R	R	R	70	R	R	R	70	R	R	R	...	..	..	..	...	..
										Boiling	N	N	N	Boiling	R	R	N	Boiling	N	N	N	Boiling	R	R	V	Boiling	R	R	R	Boiling	R	R	R	...	..	..	..	...	..
	....	....	....	....	....	....	....	....	Any form	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	N	20	N
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	R	R	[c]	R	R	N	[c]	R	R	R	[c]	R	R	N	[c]	N
	....	....	....	....	....	....	....	....	Any form	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	N	20	N
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	R	N	[c]	N	N	N	[c]	R	R	R	[c]	R	R	N	[c]	N
	....	....	....	....	....	....	....	....	Any form	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	N	20	R	R	N	...	..	..	..	20	R	R	N	...	..
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	R	N	[c]	N	N	N	...	..	..	..	...	..	..	..	...	..
	....	....	....	....	....	....	....	....	Any form	20	R	N	R	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	R	20	R
										[c]	R	N	R	[c]	R	R	R	[c]	N	N	N	[c]	R	R	N	[c]	R	R	N	[c]	R	R	R	[c]	R	R	R	[c]	R
	....	....	....	....	....	....	....	....	Any form	20	R	R	R	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	R	20	R
										[c]	R	N	R	[c]	R	R	R	[c]	R	R	N	[c]	R	R	R	[c]	R	N	N	[c]	R	R	R	[c]	R	R	R	[c]	R
	....	....	540	....	....	....	....	....	....	...	..	..	..	20	R	R	R	...	..	..	..	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	R	20	R
														Hot	R	R	R	...	..	..	..	[c]	R	R	R	Hot	R	R	..	[c]	R	R	R	[c]	R	R	R	[c]	R
	....	....	540	....	....	....	....	....	....	...	..	..	..	20	R	R	R	...	..	..	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R
														...	..	..	..	...	..	..	..	Warm	..	..	R	Warm	R	R	R	Warm	R	R	R	All	R	R	R	...	..
														Boiling	R	R	R	...	..	..	..	Boiling	R	R	R	Boiling	R	R	R										
	....	....	1035	....	....	....	....	....	....	20	R	N	N	20	R	R	..	...	..	..	..	20	R	R	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R
														[c]	R	R	..	...	..	..	..	...	..	..	..	Boiling	R	R	.:	Boiling	R	R	R	[c]	R	R	R		
	....	....	785	....	785	....	....	....	....	20	R	..	R	...	..	..	..	...	..	..	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R
										[c]	..	..	R																										
	....	....	....	....	....	....	....	....	....	20	R	R	N	20	R	R	R	20	N	N	N	20	R	..	R	20	R	R	R	20	R	R	R	20	..	..	R	...	..
										80	R	R	N	80	R	R	R	80	N	N	N	...	..	..	..	80	R	R	R	80	R	R	R						
	....	....	....	....	....	....	....	....	[d]	20	V	N	N	20	R	R	R	20	N	N	N	20	R	V	N	20	R	R	R	20	R	R	R	20	R	R	V	20	R
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	V	N	[c]	R	R	V	[c]	R	R	R	[c]	R	R	V	[c]	R
	....	....	....	....	....	....	....	....	....	20	V	N	N	20	R	R	R	20	N	N	N	20	R	V	N	20	R	R	R	20	R	R	R	20	R	R	V	20	R
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	V	N	[c]	R	R	V	[c]	R	R	V	[c]	R	R	V	[c]	R
	....	....	....	....	....	....	....	....	....	20	V	N	N	20	R	R	R	20	N	N	N	20	R	V	N	20	R	R	R	20	R	R	R	20	R	R	V	20	R
										[c]	N	N	N	[c]	R	R	R	[c]	N	N	N	[c]	R	V	N	[c]	R	R	V	[c]	R	R	R	[c]	R	R	V	[c]	R
	....	....	....	....	....	....	....	....	....	20	V	N	N	20	V	R	R	20	N	N	N	20	V	V	R	20	R	R	R	20	R	R	R	20	V	V	V	20	V
										[c]	N	N	N	[c]	N	R	R	[c]	N	N	N	[c]	N	N	V	[c]	R	R	V	[c]	R	R	R	[c]	V	V	V	[c]	V
	....	....	....	....	....	....	....	....	....	20	R	V	R	20	R	R	R	20	N	N	N	20	R	V	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R
										Boiling	N	N	N	Boiling	R	V	V	Boiling	N	N	N	Boiling	N	N	N	Boiling	R	R	N	Boiling	R	R	R	Boiling	R	R	N	Boiling	R

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[c] Above room temperature.

[d] Hardened.

PART I*b*. CORROSION-RESISTANT PROPERTIES.

												Corrosion in Media at Moderate																			
Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
20 100	R V	R V	R V	20 100	R R	R R	R R	20 100	R R	R R	R R	20 100	R V	R V	R V	20 100	R V	R V	R V	20 100	N N	20 100 Boiling	R R N	20 100	N N	20 100	R N	20 100	V V	20 100	R R
20 100	R V	R V	R V	20 100	R V	R V	R V	20 100	R R	R R	R R	20 100	R V	R V	R V	20 100	V V	V V	V V	20 ...	N	20 100 Boiling	V V N	20 100	N N	20 100	R R	20 100	V V	20 100	V V
20 100	R V	R V	R V	20 100 Boiling	R R	R R	R R V	20 100	R R	R R	R R	20 100	R R	R R	R R	20 100	V V	V V	V V	20 ...	N	20 100 Boiling	R V N	20 100	N N	20 100	V V	20 100	V V	20 100	R R
20 100	V N	V N	V N	20 100	R V	R V	R V	20 100	R R	R R	R R	20 100	V V	V V	V V	20 100	V V	V V	V V	20 100	N N	20 100 115	N N N	20 100	N N	20 100	V V	20 100	V V	20 100	R R
20 100	R V	R V	R V	20 100	R R	R R	R R	20 100	R R	R R	R R	20 100	R V	R V	R V	20 100	V V	V V	V V	20 ...	N	20 100 Boiling	N N N	20 100 Boiling	N N N	20 100	R R	20 100	V V	20 100	V V
20	V	V	V	20	5 per cent R	V	V	20	R	R	V	20	R	R	R	...	..	..	..	...	....	20	N	20	N	20	R	20	R	20	R
20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	R R R	R R R	R R R	20	R	R	R	20	.. .. ..	.. .. ..	R	20 70 Boiling	N N N	20 70 Boiling	R R N	20	R	20	R	20	R	20	R
20 70 Boiling	R R R	R R R	R R N	20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	R R R	R R R	R R R	20	R	R	R	20	.. .. ..	.. .. ..	R	20 70 Boiling	N N N	20 70 Boiling	R R N	20	R	20	R	20	R	20	R
20 70 Boiling	R R R	R R R	R R V	20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	R R R	R R R	R R R	20	R	R	R	20	.. .. ..	.. .. ..	R	20 70 Boiling	N N N	20 70 Boiling	R R N	20	R	20	R	20	R	20 70 Boiling	R R R
20 *c*	R R	R R	R R	20 *c*	R R	R R	N N	20 *c*	R R	R R	R R	20 *c*	R R	R R	N N	20 *c*	N N	R N	R R	... ...	....	20 *c*	R R	20 *c*	N N	20 *c*	V V	20 *c*	R R	20 *c*	R R
20 *c*	R R	R R	R N	20 *c*	R N	R N	N N	20 *c*	R R	R R	R R	20 *c*	R R	R R	N N	20 *c*	N N	R N	R R	... ...	....	20 *c*	V V	20 *c*	N N	20 *c*	V V	20 *c*	R R	20 *c*	R R
20 *c*	R R	R R	N N	20 *c*	R N	R N	N N	... ...	.. ..	.. ..	.. ..	20 ...	R ..	R ..	N ..	... ...	.. ..	.. ..	.. ..	... ...	....	20 *c*	V V	20 *c*	N N	20 *c*	R R	20 *c*	R R	20 *c*	R R
20 *c*	R R	R R	R N	20 *c*	R R	R R	N N	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	... ...	....	20 *c*	V V	20 *c*	N N	20 *c*	R R	20 *c*	R R	20 *c*	R R
20 *c*	R R	R R	R R	20 *c*	R R	R N	N N	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	... ...	....	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R
20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	R	20	R	R	R	...	....	20	R (80 per cent C. P. Max.)	...	....	20	R	20	R	20	R
c	R	R	R	Hot	R	R	..	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	....	Hot	R (80 per cent C. P. Max.)	...	....	...	....	Hot	R	Hot	R
20 Warm Boiling	R .. R	R .. R	R R R	20 Warm Boiling	R R R	R R R	R R R	20 Warm	R R	R R	R R	20 All	R R	R R	R R	20 ...	R ..	R ..	R ..	... ...	....	20 Warm	R (Dilute) R (50 per cent Max.)	... ...	....	20 ...	R	20 *c*	R R	20 *c*	R R
20 ...	R ..	R ..	.. ..	20 Boiling	R R	R R	R ..	20 Boiling	R R	R R	R R	20 *c*	R R	R R	R R	20	R	R	R	...	....	...	....	...	....	20	R	20	R	20	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	..	..	...	....	20	R	...	....	...	....	20	R	20	R
20 ...	R ..	.. ..	R ..	20 80	R R	R R	R R	20 80	R R	R R	R R	20	..	..	R	...	..	..	..	20	N	20	R	...	....	...	....	20	R	20	R
20 *c*	R R	V V	N N	20 *c*	R R	R R	R V	20 *c*	R R	R R	R R	20 *c*	R R	R R	V V	20 *c*	R R	R R	V V	20 *c*	N N	20 *c*	R N	20 *c*	N N	20 *c*	R V R V	20 *c*	R R	20 *c*	R R
20 *c*	R R	V V	N N	20 *c*	R R	R R	R V	20 *c*	R R	R R	R V	20 *c*	R R	R R	V V	20 *c*	R R	R R	V V	20 *c*	N N	20 *c*	R N	20 *c*	N N	20 *c*	R V R V	20 *c*	R R	20 *c*	R R
20 *c*	R R	V V	N N	20 *c*	R R	R R	R V	20 *c*	R R	R R	R R	20 *c*	R R	R R	V V	20 *c*	R R	R R	V V	20 *c*	N N	20 *c*	R N	20 *c*	N N	20 *c*	R V R V	20 *c*	R R	20 *c*	R R
20 *c*	V N	V N	R V	20 *c*	R R	R R	R V	20 *c*	R R	R R	R R	20 *c*	V V	V V	V V	20 *c*	V V	V V	V V	20 *c*	N N	20 *c*	N N	20 *c*	N N	20 *c*	R V R V	20 *c*	R R	20 *c*	V V
20 Boiling	R N	V N	N N	20 Boiling	R R	R R	R N	20 Boiling	R R	R R	R R	20 Boiling	R R	R R	R N	20 Boiling	R R	R R	R N	20 Boiling	N N	20 Boiling	R N	20 Boiling	N N	20 Boiling	R V R V	20 Boiling	R R	20 Boiling	R R

[d] Hardened.

PLATE VI.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART I*b*.

derate Temperatures																
and able es	Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Atmosphere		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Medium			
R R	20 100	V V	20 100	V V	20 100	R R	20 100	R R	20 100	 V	...	....	....	....	Allegheny Metal..........	Allegheny Steel Co.
V V	20 100	V V	20 100	V V	20 ...	R	20 100	V V	20 100	V V	...	....	....	....	Ascoloy 33...............	
R R	20 100	V V	20 100	V V	20 100	R R	20 100	R R	20 100	V V	...	....	....	....	Ascoloy 44...............	
R R	20 100	V V	20 100	V V	20 100	V V	20 100	V V	20 100	N N	...	....	....	....	Ascoloy 55...............	
V V	20 100	V V	20 100	V V	20 100	V V	20 100	V V	20 100	V V	...	....	....	....	Ascoloy 66...............	
R	20	V	20	V	20	R	20	R	20	N	...	R R R	Steam............ Soap.............. Tannic Acid.........	....	Bethlehem Stainless Steel, Type "A"............	Bethlehem Steel Co.
R	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Enduro KA 2.............	Central Alloy Steel Corp. (Republic Steel Corp.)
R	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Enduro S.......	
R R R	...	....	20	N	20	R	20	R	20	R	...	....	....	....	Enduro A................	
R R	20 *c*	V V	20 *c*	N N	20 *c*	R R	20 *c*	R R	20 *c*	N N	...	....	....	Any form	Stainless "A"............	Colonial Steel Co.
R R	20 *c*	V V	20 *c*	N N	20 *c*	R R	20 *c*	R R	20 *c*	N N	...	....	....	Any form	Stainless "B"............	
R R	20 *c*	V V	20 *c*	N N	20 *c*	R R	20 *c*	R R	20 *c*	N N	...	....	....	Any form	Stainless "I"............	
R R	20 *c*	V V	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	...	....	....	Any form	Stainless "N"............	
R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20	R	Sulfite Pulp Liquor	Any form	Stainless "U"............	
R R	20 Hot	R R	20 Hot	R R	20 Hot	R R	20 Hot	R R	20 Hot	R R	...	....	....	....	Rezistal No. 7............	Crucible Steel Co. of America
R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	20 *c*	R R	...	....	....	....	Rezistal KA-2............	
R	...	....	20	R	20	R	20	R	20	R	...	....	....	....	Rezistal No. 4............	
R	...	....	20	R	20	R	20	R	...	....	...	....	....	....	Cyclops No. 17 Metal......	Cyclops Steel Co.
R	...	....	...	....	...	....	20	R	20	R	...	....	....	....	Durimet................	Duriron Co.
R R	20 *c*	V V	20 *c*	V V	20 *c*	R R	20 *c*	R R	20 *c*	V V	...	....	....	....	Sterling Stainless Steel, Type A	Firth-Sterling Steel Co.
R R	20 *c*	V V	20 *c*	V V	20 *c*	R R	20 *c*	R R	20 *c*	V V	...	....	....	....	Sterling Stainless Steel, Type BHH............	
R R	20 *c*	V V	20 *c*	V V	20 *c*	R R	20 *c*	R R	20 *c*	V V	...	....	....	....	Sterling Stainless Steel, Type MG............	
V V	20 *c*	V V	20 *c*	V V	20 *c*	V V	20 *c*	V V	20 *c*	N N	...	....	....	....	Sterling Stainless Steel, Type T............	
R R	20 Boiling	V V	20 Boiling	V V	20 Boiling	R R	20 Boiling	R R	20 Boiling	V V	...	....	....	....	Sterling Nirosta..........	

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART II*a*

Compositions and Physical and Mechanical Properties

Latrobe Electric Steel Co.

Ludlum Steel Co.

Midvale Co.

Rustless Iron Corp. of America

Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured								Types of Service for Which Recommended				Typical Applications	Specific Gravity	Melting Range (Liquidus and Solidus Temperatures), deg. Cent.	C
			Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical				Mean
Latrobe Electric Steel Co.	Stainless Iron "L"	C 0.10,[b] Si 0 50,[b] Mn 0.40, Cr 12.0	..	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	....	7.65	1495	...
	Regular Stainless Steel	C 0.35, Si 0.50,[b] Mn 0.35, Cr 13.5	...	✓	✓	✓	✓	✓	✓	✓	✓	...	✓	...	Cutlery and allied purposes	7.75	1510	...
	Stainless Iron "N"	C 0.10,[b] Si 0.50,[b] Mn 0.40, Cr 16.5	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	....	....	....	...
	Lusterite Stainless Steel	C 0.85, Si 0.50,[b] Mn 0.35, Cr 17.25	...	✓	✓	✓	✓	✓	✓	✓	✓	...	...	...	Cutlery, dental and surgical instruments	....	....	...
	Hy-Glo Stainless Steel	C 0.62, Si 0.50,[b] Mn 0.35, Cr 17.0	...	✓	✓	✓	✓	✓	✓	✓	✓	...	✓	...	Cutlery and allied purposes, valve; piston rods and pump rods	....	....	...
	Stainless Iron "H"	C 0.10,[b] Si 0.50,[b] Mn 0.50 Cr,[b] 19.0	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	....	....	....	...
Ludlum Steel Co	Enduro A	C 0.09,[b] Cr 17.5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	Corrosion resistant, heat resistant to 870° C	7.62	1540 to 1315	(20 to 0.00
	Delhi Hard	C 1.00, Cr 17.5	...	✓	✓	✓	...	...	...	...	✓	✓	✓	..	Corrosion-resistant parts of great hardness	7.63	1510 to 1315	(20 to 0.00
	Nevastain A	C 0.32, Cr 13.5	✓	✓	✓	...	...	...	...	...	✓	✓	...	...	Cutlery and non-corrosive machine parts	7.63	1510 to 1315	(20 to 0.00
	Nevastain B	C 0.70, Cr 17.0	✓	✓	✓	...	...	..	..	..	✓	✓	...	..	Cutlery and non-corrosive machine parts	7.63	1510 to 1315	(20 to 0.00
	Enduro S	C 0.12, Cr 12.25	✓	✓	✓	✓	✓	✓	✓	..	✓	✓	...	...	Machine parts	7.63	....	(22 to 0.00
	KM 1	C 0.12,[b] Cr 13.0, Ni 2.0[b]	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Highly stressed machine parts, piston rods, valves, etc.	7.73	1435	0.00
	KA 2	C 0.12, Cr 18.5, Ni 8.5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	..	Chemical industry, ornamental and car trim, wire products, utensils	7.86	1400	0.000
	KA 2-S	C 0.07, Cr 18.5, Ni 8.5	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	For severe corrosion work, high temperature with corrosion	7.86	1400	0.000
	KA 4	C 0.20, Cr 19.0, Ni 10.0, Mo 3.25	✓	✓	✓	✓	✓	..	✓	✓	✓	✓	✓	..	For use with sulfite liquors in pulp mills and for acetic acid	....	1485	0.000
Midvale Co.	V-2-A	C 0.09, Mn 0.50,[b] Si 0.50, Cr 18.00 Ni 9.15	✓	✓	✓	...	...	...	...	...	✓	✓	...	...	Corrosion resistance to certain chemicals, strength at elevated temperature and atmospheric corrosion resistance	7.88	1450	0.000
	Nicral "C"	C 0.30, Mn 1.50, Si 1.50, Ni 26.5, Cr 11.00	✓	✓	✓	...	...	...	...	...	✓	✓	...	...	Cementation boxes, lead pots, salt baths, pyrometer tubes, glass blow pipes, parts of mechanical stokers, conveyors, crucibles for casting white metal, metallic muffles, recuperator plates	8.05	1500	0.000
	ATV-1	C 0.30, Mn 1.50, Si 0.20, Ni 36.0, Cr 11.0	✓	✓	✓	...	...	...	..	...	✓	✓	..	✓	Parts of valves for steam engines, turbine blades, centrifugal pumps, exhaust valves, rheostats, heating elements	8.05	1450	0.000
	Midvale HR	C 0.35, Mn 0.55, Si 1.40, Cr 19.50, Ni 7.25, W 4.0	✓	✓	✓	...	...	...	...	..	✓	✓	✓	...	Recuperator parts, explosion motor valves, cast pyrometer tubes, furnace racks, high pressure gas burner nozzles	8.03	....	...
	"B.T.G"	C 0.30, Mn 1.25, Si 0.65, Ni 60.5, Cr 11.5, W 2.5	✓	✓	✓	...	...	...	...	..	✓	✓	...	...	Apparatus for chemical synthesis, autoclaves for chemical reaction, injector discharge tubes, apparatus subjected to static or dynamic stresses at high temperatures, valves, pressure generators, molds or other equipment in glass industry	8.45	1450	...
	ATV-3	C 0.47, Mn 1.30, Si 1.35, Ni 26.5, Cr 14.0, W 3.40	✓	✓	✓	...	...	...	..	..	✓	✓	✓	...	Gas engine valves, gas turbine rotors, Diesel engine valves, steam turbines	8.1	....	...
Rustless Iron Corp. of America	Defirust	C 0.10,[b] Mn 0.40,[b] Si 0.50,[b] Cr 13.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	..	....	7.69	1495	(20 to 1 0.000
	Special Defirust	C 0.10,[b] Mn 0.40,[b] Si 0.50,[b] Cr 17.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	..	....	7.66	1485 to 1370	(20 to 2 0.000
	Defistain	C 0.18,[b] Mn 0.50,[b] Si 0.50,[b] Cr 18.0 Ni 8.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	....	7.86	1470	0.000
	Defiheat	C 0.25, Mn 0.50,[b] Si 0.75,[b] Cr 28 5	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	....	7.62	1540	(20 to 1 0.000

[a] Annealed

[b] Maximum.

[c] Approximate.

[d] Properties within this ran

PART II*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PR

Physical Properties								Mechanical Properties at Room Temperature															
Coefficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Form for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear
Mean 0 to 100° C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.				
....	....	....	....	....	......	....	....	....	78 000 to 171 000	65 000 to 160 000	......	25.0 to 4.5	65.0 to 9.5	......	365 to 170	....	....	....	32.5 to 80+	....	......	....	
....	....	....	....	....	......	....	....	....	96 000 to 233 000	81 000 to 220 000	......	28.0 to 1.0	60.0 to 0.0	......	200 to 500	....	....	....	9.0 to 57.5	....	......	....	
....	....	....	....	....	......	....	....	....	66 000 to 149 000	44 000 to 121 000	......	25.0 to 11.0	65.0 to 32.0	......	165 to 315	....	....	....	20.0 to 80+	....	......	....	
....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	....	92 000 to 278 000	76 000 to 250 000	......	12.5 to 2.5	40.0 to 2.5	......	240 to 585	....	....	....	2.5 to 19.0	....	......	....	
....	....	....	....	....	......	....	....	....	74 000 to 95 000	50 000 to 70 000	......	27.5 to 15.5	61 0 to 28.0	......	170 to 205	....	....	....	3.5 to 58.0	....	......	....	
(20 to 100° C.) 0.0000104	(20 to 800° C.) 0.0000118	....	....	....	......	....	....	Hot rolled bars	60 000 to 75 000	40 000 to 50 000	40 000	32.0	65.0 to 60.0	......	190 to 210	"B" 85.0 to 90.0	25.0 to 30.0	....	20.0 to 30.0	....	......	....	
(20 to 100° C.) 0.0000104	(20 to 800° C.) 0.0000118	....	....	....	......	....	....	Hot rolled bars	110 000	40 000 to 50 000	25 000 to 45 000	14.0 to 12.0	18.0	29 500 000	220 to 230	....	30.0 to 35.0	....	7.0 to 10.0	....	......	....	
(20 to 100° C.) 0.0000093	(20 to 800° C.) 0.0000119	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	....	
(20 to 100° C.) 0.0000098	(25 to 800° C.) 0.0000119	....	....	....	......	....	....	Hot rolled bars[a]	90 000 to 95 000	40 000 to 45 000	25 000	26.5	50.0 to 45.0	......	180 to 210	"B" 85.0 to 95.0	27.0 to 32.0	....	30.0 to 25.0	....	......	....	
(22 to 100° C.) 0.0000104	(22 to 800° C.) 0.0000118	....	....	....	......	....	....	Forgings[a]	100 000	75 000 to 80 000	50 000 to 60 000	23.0	70.0 to 65.0	......	212	....	....	....	....	....	......	....	
								Hot rolled bars	140 000 to 150 000	75 000	50 000	13.0	46.0	......	255	28.0 to 32.0	30.0 to 35.0	....	25.0 to 30.0	....	......	....	
0.000010	....	0.072[c]	....	....	......	73.0	....	Forgings	135 000	90 000	......	14.0	60.0	......	180 to 250	....	....	....	....	....	......	....	
								Hot rolled bars	135 000	90 000	......	14.0	60.0	......	180 to 250								
0.000016	(600 to 1000° C.) 0.000019	....	....	0.118	......	(20 to 100° C.) 81.5	(500 to 800° C.) 112.0	Castings[a]	70 000	30 000	......	50.0	....	......	....	....	....	....	....	....	......	....	
								Forgings[a]	90 000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120				
								Hot rolled bars[a]	90 000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120				
								Plates and sheets[a]	90 000	......	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120				
								Shapes[a]	90 000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120				
								Tubes[a]	90 000	40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120				
								Wire[a]	100 000 to 150 000	......	......	60.0 to 25.0	....	......	....	"B" 76.0 to "C" 30.0							
0.000016	(600 to 1000° C.) 0.000019	0.052	....	0.118	......	(20 to 100° C.) 81.5	(500 to 800° C.) 112	Forgings[a]	80 000	30 000	......	68.0	77.0	25 000 000	135	....	....	100 to 110	115 to 120	....	......	....	
								Hot rolled bars[a]	80 000	30 000	......	68.0	77.0	25 000 000	135	....	....	100 to 110	115 to 120	....	......	....	
								Plates and sheets[a]	80 000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	
								Shapes[a]	80 000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	
								Tubes[a]	80 000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	
								Wire[a]	100 000	......	......	60.0	....	......	....	"B" 76.0	....	....	....	...	......	....	
0.000019	....	0.052	....	....	......	....	....	Forgings[a]	96 000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	
								Hot rolled bars[a]	96 000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	
								Plates and sheets[a]	96 000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	
0.0000183	....	....	....	....	......	....	....	Forgings[e]	90 000 to 115 000	35 000 to 75 000	35 000 to 70 000	60.0 to 30.0	75.0 to 50.0	......	140 to 200	"B" 70.0 to 90.0	....	....	....	....	35 000	....	
								Hot rolled bars[e]	90 000 to 115 000	35 000 to 75 000	35 000 to 70 000	60.0 to 30.0	75.0 to 50.0	......	140 to 200								
0.0000167	....	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	....	
0.0000136	....	0.020	(600° C.) 0.052	....	......	100.0	....	Hot rolled bars	85 000 to 102 000	......	......	28.0 to 12.0	80.0 to 50.0	26 000 000	216	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Hot rolled bars	85 000 to 135 000	50 000 to 90 000	......	37.0 to 20.0	50.0 to 30.0	......	....	....	....	....	....	....	......	....	
....	....	0.018	(600° C.) 0.050 (800° C.) 0.065	....	......	105.0	....	Castings	65 000 to 75 000	35 000 to 45 000	21 000 to 30 000	30.0 to 25.0	30.0 to 25.0	30 000 000	....	"B" 71.0 to 86.0	....	....	....	....	......	....	
								Forgings	99 000 to 106 000	42 000 to 46 000	27 000 to 28 000	50.0 to 36.0	50.0 to 36.0	......	....	"B" 88.0 to 89.0							
....	....	....	....	....	......	....	....	Forgings	108 000	55 000	45 000	24.2	43.7	......	187	20.0	....	17.5	....	....	......	....	
								Hot rolled bars	89 600	56 000	......	20.0	....	......	....	....	....	35.0	....	....	......	....	
(20 to 100° C.) 0.0000109	(20 to 1000° C.) 0.0000136	0.096	....	0.159	......	60.7	....	....	68 000 to 180 000	46 000 to 168 000	25 000 to 130 000	37.0 to 10.0	78.0 to 50.0	......	130 to 350	....	....	....	....	....	......	....	
(20 to 250° C.) 0.0000099	(250 to 700° C.) 0.0000104	0.072	....	0.151	......	63.1	....	....	75 000 to 85 000	51 000 to 65 000	37 000 to 45 000	33.0 to 23.0	69.0 to 54.0	......	161 to 170	....	....	....	....	....	......	....	
0.000016	(0 to 1000° C.) 0.000019	0.069	....	0.116	......	....	....	....	85 000 to 160 000	34 000 to 150 000	29 000 to 120 000	61.0 to 18.0	75.0 to 52.0	......	135 to 260	....	....	....	....	....	......	....	
(20 to 100° C.) 0.0000102	(20 to 1000° C.) 0.0000134	0.059	....	0.142	......	63.9	....	[a]	75 000 to 100 000	55 000 to 80 000	45 000 to 65 000	35.0 to 25.0	65.0 to 45.0	......	160 to 200	....	....	....	....	....	......	....	

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n this range depend on section and amount of cold working.

[i] Design stress $\frac{2}{3}$ values given.

IIa. COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																			Mechanical Properties at Elevated Temperatures				
						Hardness Number			Impact Strength														
Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.	Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination
000 to 71 000	65 000 to 160 000	......	25.0 to 4.5	65.0 to 9.5	......	365 to 170	....	....	....	32.5 to 80+	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 33 000	81 000 to 220 000	......	28.0 to 1.0	60.0 to 0.0	......	200 to 500	....	....	....	9.0 to 57.5	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 49 000	44 000 to 121 000	......	25.0 to 11.0	65.0 to 32.0	......	165 to 315	....	....	....	20.0 to 80+	....	......	....	....	......	....	......	....	....	....	....	....	....
.....	......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 78 000	76 000 to 250 000	......	12.5 to 2.5	40.0 to 2.5	......	240 to 585	....	....	....	2.5 to 19.0	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 5 000	50 000 to 70 000	......	27.5 to 15.5	61.0 to 28.0	......	170 to 205	....	....	....	3.5 to 58.0	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 5 000	40 000 to 50 000	40 000	32.0	65.0 to 60.0	......	190 to 210	"B" 85.0 to 90.0	25.0 to 30.0	....	20.0 to 30.0	....	......	....	....	......	....	......	....	....	....	....	....	....
0 000	40 000 to 50 000	25 000 to 45 000	14.0 to 12.0	18.0	29 500 000	220 to 230	....	30.0 to 35.0	....	7.0 to 10.0	....	......	....	....	......	....	......	....	....	....	....	....	....
....	......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 5 000	40 000 to 45 000	25 000	26.5	50.0 to 45.0	......	180 to 210	"B" 85.0 to 95.0	27.0 to 32.0	....	30.0 to 25.0	....	......	....	....	......	....	......	....	....	....	....	....	....
0 000	75 000 to 80 000	50 000 to 60 000	23.0	70.0 to 65.0	......	212	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
000 to 0 000	75 000	50 000	13.0	46.0	......	255	28.0 to 32.0	30.0 to 35.0	....	25.0 to 30.0	....	......	....	....	....	....	......	....	....	....	....		
5 000	90 000	......	14.0	60.0	......	180 to 250	....	....	....	....	....	......	....	....	......	....	......	....	....	540 595	7 000 4 000	1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests
5 000	90 000	......	14.0	60.0	......	180 to 250																	
0 000	30 000	......	50.0	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	480 540 595 650 705	20 000 15 000 8 500 5 500 3 500	1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests
0 000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120													
0 000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120													
000	......	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120													
000	35 000 to 40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120													
000	40 000	......	60.0 to 55.0	75.0 to 70.0	27 500 000	135 to 145	....	....	100 to 110	115 to 120													
000 to 0 000	......	......	60.0 to 25.0	....	......	....	"B" 76.0 to "C" 30.0																
000	30 000	......	68.0	77.0	25 000 000	135	....	....	100 to 110	115 to 120	....	......	....	....	......	....	......	....	....	480	20 000	1 per cent in 100 000 hours	Long time tests
000	30 000	......	68.0	77.0	25 000 000	135	....	....	100 to 110	115 to 120	....	......	....	....	......	....	......	....	....	540	15 000	1 per cent in 100 000 hours	
000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	....	......	....	......	....	....	595	8 500	1 per cent in 100 000 hours	
000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	....	......	....	......	....	....	650	5 500	1 per cent in 100 000 hours	
000	30 000	......	68.0	77.0	25 000 000	135 to 140	....	....	....	....	....	......	....	....	......	....	......	....	....	705[i]	3 500	1 per cent in 100 000 hours	
000	......	......	60.0	....	......	....	"B" 76.0	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	
000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	....	......	....	......	....	....	....	....	....	....
000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	....	......	....	......	....	....	....	....	....	....
000	50 000	......	60.0	70.0 to 75.0	27 500 000	....	....	....	....	115 to 120	....	......	....	....	......	....	......	....	....	....	....		
000 to 5 000	35 000 to 75 000	35 000 to 70 000	60.0 to 30.0	75.0 to 50.0	......	140 to 200	"B" 70.0 to 90.0	....	....	....	....	35 000	....	....	......	....	11 000 000	....	....	....	....	....	....
000 to 5 000	35 000 to 75 000	35 000 to 70 000	60.0 to 30.0	75.0 to 50.0	......	140 to 200																	
....	......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
00 to 2 000	......	......	28.0 to 12.0	80.0 to 50.0	26 000 000	216	....	....	....	....	....	......	....	....	......	....	......	....	....	350 400 425 450	45 500 42 650 39 800 37 000	....	Recommended
00 to 5 000	50 000 to 90 000	......	37.0 to 20.0	50.0 to 30.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
00 to 000	35 000 to 45 000	21 000 to 30 000	30.0 to 25.0	30.0 to 25.0	30 000 000	....	"B" 71.0 to 86.0	....	....	....	....	......	....	....	......	....	10 800 000	....	....	600 650 700 750 800	6 400 3 900 2 850 2 150 1 600	....	Recommended for continuous loads
00 to 000	42 000 to 46 000	27 000 to 28 000	50.0 to 36.0	50.0 to 36.0	......	....	"B" 88.0 to 89.0																
000	55 000	45 000	24.2	43.7	......	187	20.0	....	17.5	....	....	......	....	....	......	....	......	....	....	....	....	....	....
600	56 000	......	20.0	....	......	....	....	....	35.0	....	....	......	....	....	......	....	......	....	....	....	....	....	....
00 to 000	46 000 to 168 000	25 000 to 130 000	37.0 to 10.0	78.0 to 50.0	......	130 to 350	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
00 to 000	51 000 to 65 000	37 000 to 45 000	33.0 to 23.0	69.0 to 54.0	......	161 to 170	....	....	....	....	....	......	....	....	......	....	......	....	....	95 205 315 425 540	42 000 28 000 21 000 10 000 5 000	1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests
00 to 000	34 000 to 150 000	29 000 to 120 000	61.0 to 18.0	75.0 to 52.0	......	135 to 260	....	....	....	....	....	......	....	....	......	....	......	....	....	540 595 650 705 760 815	15 200 8 500 5 400 3 400 1 900 900	1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests
00 to 000	55 000 to 80 000	45 000 to 65 000	35.0 to 25.0	65.0 to 45.0	......	160 to 200	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....

stress ½ values given.

PLATE VII.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART II*a*.

	Fabricating Properties														Trade Name of Alloy	Manufacturer
		Hot Working		Cold Working	Welding							Precautions to be Observed				
hod of ress nination	Machining	Optimum Temperature Range, deg. Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance	Brazing	Soldering	In Design	In Fabricating	In Use		
......	About the same as carbon steels	925 to 1150	....	......	..	✓	..	✓	..	✓	✓	....	Welds should be annealed	Corrosion may occur at welds	Stainless Iron "L".......	Latrobe Electric Steel Co.
......	About the same as carbon steels	925 to 1095	Air hardening	......	..	✓	..	✓	..	✓	✓	....	Welds should be annealed	Corrosion may occur at welds	Regular Stainless Steel...	
......	About the same as carbon steels	925 to 1120	....	......	..	✓	..	✓	..	✓	✓	....	Welds should be annealed	Corrosion may occur at welds	Stainless Iron "N".......	
......	About the same as carbon steels	925 to 1095	Air hardening	......	..	✓	..	✓	..	✓	✓	....	Welds should be annealed	Corrosion may occur at welds	Lusterite Stainless Steel ..	
......	About the same as carbon steels	925 to 1095	Air hardening	......	..	✓	..	✓	..	✓	✓	....	Welds should be annealed	Corrosion may occur at welds	Hy-Glo Stainless Steel....	
......	About the same as carbon steels	925 to 1150	....	......	..	..	..	..	..	..	..	....	Welds should be annealed	Corrosion may occur at welds	Stainless Iron "H"......	
......	....	1010 to 1150	....	......	..	✓	..	✓	✓	✓	✓	....	....	....	Enduro A.............	Ludlum Steel Co.
......	....	1035 to 1150	....	......	..	✓	..	✓	✓	..	✓	....	....	Must be heat treated to develop full corrosion resistance	Delhi Hard............	
......	....	1010 to 1150	....	......	..	✓	..	✓	✓	✓	✓	....	....	....	Nevastain A...........	
......	....	1010 to 1150	....	......	..	✓	..	✓	✓	✓	✓	....	....	....	Nevastain B...........	
......	....	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Enduro S..............	
ne tests	Same as ordinary steel of equal strength	1095 to 1150	Do not work below 900° C.	30 max.	..	✓	..	✓	..	..	..	....	Use heat-treated materials	For continuous heating do not exceed 620° C.	KM 1.................	
e tests	Three-quarters to half that of common steel under special methods	1010 to 1205	705 to 955° C. pro-range hibited	40 max.	..	✓	..	✓	✓	✓	✓	....	Annealed materials essential	Continuous heating between 480 and 870° C. dangerous. Recarburizes at +900° C.	KA 2.................	
e tests	Three-quarters to half that of common steel under special methods	1010 to 1205	705 to 955° C. prohibited range	40	..	✓	..	✓	✓	✓	✓	....	....	Continuous heating between 705 to 870° C. dangerous. Recarburizes at 900° C.	KA 2-S...............	
....	....	....	....	......	..	✓	..	✓	..	..	..	....	Use heat treated materlal	....	KA 4.................	
.....	Machineable	1205	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	V-2-A................	Midvale Co.
.....	Fair	1035 to 1095	....	......	..	✓	..	✓	..	..	..	Shrinkage of 0.264 in. per foot should be allowed	Castings should be air cooled from 900° C. before using	....	Nicral "C"............	
nded	Slightly tougher than ordinary carbon steel	980 to 1150	....	......	..	✓	..	✓	..	✓	✓	....	....	....	ATV-1................	
.....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Midvale HR...........	
nded tinuous	Easily machined	1150	Make small reduction per blow	......	..	✓	..	✓	..	✓	✓	....	....	....	"B.T.G"...............	
....	Good	1035	Make small reduction per pass.	......	..	✓	..	✓	..	✓	✓	....	Heat carefully and work carefully	....	ATV-3................	
.....	Machines readily with properly designed tools	955 to 1035	....	......	✓	✓	✓	✓	✓	✓	✓	....	Anneal welds	....	Defirust..............	Rustless Iron Corp. of America
e tests	Machines readily with properly designed tools and reduced speeds	955 to 1035	....	......	✓	✓	✓	✓	✓	✓	✓	....	Anneal welds	....	Special Defirust.........	
e tests	Somewhat difficult	1035 to 1150	....	......	✓	✓	✓	✓	✓	✓	✓	....	....	....	Defistaln..............	
.....	Somewhat difficult	1035 to 1095	....	......	..	..	..	..	✓	..	..	....	....	....	Defiheat...............	

PART IIb

Corrosion-Resistant Properties

Latrobe Electric Steel Co.

Ludlum Steel Co.

Midvale Co.

Rustless Iron Corp. of America

R = Recommended N = Not recommended. V = Varies with individual conditions; consult manufactur

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																						
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydro-carbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen		Chlorine		Hydr Aci
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation
Latrobe Electric Steel Co.	Stainless Iron "L"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Regular Stainless Steel	815	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Stainless Iron "N"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Lusterite Stainless Steel	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Hy-glo Stainless Steel	815	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Stainless Iron "H"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ludlum Steel Co.	Enduro A	870	....	870	....	870	....	870	....	870	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Enduro S	595	....	595	....	595	....	595	....	595	....	595	....	....	....	....	....	....	....	....	....	....	....	....
	KM 1	595	....	595	....	595	....	595	....	595	....	595	....	....	....	....	....	....	....	....	....	....	....	....
	KA 2	870	....	870	....	870	....	870	....	870	....	870	....	480	....	....	....	....	....	....	....	....	....	....
		480	[e]	480	[e]	480	[e]	480	[e]	480	[e]	480	[e]	480	[e]	....	....	....	....	....	....	....	....	....
	KA 2-S	870	....	870	....	870	....	870	....	870	....	870	....	705	....	....	....	....	....	....	....	....	....	....
		705	[e]	705	[e]	705	[e]	705	[e]	705	[e]	705	[e]	....	....	....	....	....	....	....	....	....	....	....
	KA 4	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Midvale Co.	V-2-A	925	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Nicral "C"	815	....	815	....	815	....	815	....	815	....	815	....	....	....	....	....	....	....	....	....	....	....	....
	ATV-1	815	....	815	....	595	....	595	....	595	....	595	....	....	....	....	....	....	....	....	....	....	....	....
	Midvale HR	900	....	900	....	900	....	900	....	900	....	900	....	900	....	900	....	....	....	900	....	....	....	....
	"B. T. G"	800	....	800	....	800	....	800	....	800	....	800	....	....	....	....	....	....	....	650	....	....	....	....
	ATV-3	950	....	950	....	950	....	950	....	950	....	950	....	540	....	540	....	....	....	....	....	....	....	....
Rustless Iron Corp. of America	Defirust	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Special Defirust	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Defistain	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Defiheat	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

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[c] Above room temperature.

[e] Under pressure.

PART II*b*. CORROSION-RESISTANT PROPERTIES

anufacturer.

	Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia		Fused Caustic Alkalis		Fused Chlorides			Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium a Magnesiu Brines	
lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Form of Material	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	V V	V V	V V	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	V V
	....	....	....	....	....	....	....	....	....	20 c	N N	N N	N N	20 c	R R	R R	R R	20 c	N N	N N	N N	20 c	R R	R R	N N	... ...	.. ..	.. ..	.. ..	... ...	.. ..	.. ..	.. ..	20 c	R R	R R	R R	20 c	R R
	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..
	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..
	....	....	480	....	315	....	....	....	....	20	N	..	N	20	R	R	R	20	N	N	N	20	R	R	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R
	....	....	480	e	....	....	....	....	....	c	N	..	N	Boiling	R	R	R	c	N	N	N	Boiling	R	R	N	c	R	R	R	c	R	R	R	c	R	R	R	c	R
	....	....	705	....	315	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R
	....	....	705	e	....	....	....	....	....	c	N	N	N	Boiling	R	R	R	c	N	N	N	Boiling	R	R	N	c	R	R	R	c	R	R	R	c	R	R	R	c	R
	....	....	....	....	....	....	....	....	....	20 c	.. ..	N N	.. ..	20 c	R R	R R	R R	20 c	.. ..	N N	.. ..	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R
	....	....	....	....	....	....	....	....	. .	20 c	R N	N N	N N	20 ...	R ..	R ..	R ..	... ...	.. ..	.. ..	.. ..	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R
	....	....	....	....	....	....	....	....	. .	20 c	R N	R N	R N	20 c	V V	V V	V V	20 ...	N ..	N ..	N ..	... ...	.. ..	.. ..	.. ..	20 c	R R	R R	R R	20 c	R R	R R	R R	20 ...	R ..	R ..	R ..	20 ...	R ..
	....	....	....	....	....	....	....	....	.	20	R	R	R	...	..	..	..	20	R	R	R	...	..	..	..	20	R	R	R	20	R	R	R	20 ...	R ..	R ..	R ..	20 ...	R ..
	....	....	....	....	....	....	....	....	.	20 70 Boiling	V N N	V N N	V N N	20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	N N N	N N N	N N N	20 70 Boiling	R R R	R R R	R R R	20 70 Boiling	R R N	R R N	R R N	20 70 Boiling	R R R	R R R	R R R	20 ...	R ..	R ..	R ..	20 ...	R ..
	....	....	650	....	....	....	....	....	.	20 c	R R	R R	R R	... ...	.. ..	.. ..	.. ..	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R	R R	R R	20 c	R R
	....	....	....	....	....	....	....	....	.	20 c	R N	R N	R N	20 c	V V	V V	V V	20 c	R N	R N	R N	... ...	.. ..	.. ..	.. ..	20 ...	R ..	R ..	R ..	20 ...	R ..	R ..	R ..	20 c	R R	R R	R R	20 c	R R
	....	....	....	....	....	....	....	....	.	... Boiling	N N	N N	N N	... ...	R ..	R ..	N ..	... ...	N ..	N ..	N ..	... ...	R ..	N ..	N ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	15 80	R N	R N	R N	...	R
	....	....	....	....	....	....	....	....	....	... Boiling	N N	N N	N N	... ...	R ..	R ..	R ..	... ...	N ..	N ..	N ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	15 80	R R	R R	R R	...	R
	....	....	....	....	....	....	....	....	....	... Boiling	N R	N R	N R	... ...	R ..	R ..	R ..	... ...	N ..	N ..	N ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	15 80	R R	R R	R R	...	R
	....	....	....	....	....	....	....	....	....	... Boiling	N R	N R	N R	... ...	R ..	R ..	R ..	... ...	N ..	N ..	N ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	... ...	R ..	R ..	R ..	15 80	R R	R R	R R	...	R

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[j] All temperatures.

PART II*b*. CORROSION-RESISTANT PROPERTIES.

Corrosion in Media at Moderate Temperatures

Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	V	20	N	20	R	20	N	20	V	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	V	V	V	c	N	c	R	c	N	c	V	c	R	c	R
20	R	R	N	...	..	..	..	...	..	..	..	20	R	R	R	20	R	R	R	20	N	20	N	20	N	20	R	20	N	20	N
c	R	R	N	...	..	..	..	...	..	..	..	c	R	R	R	c	R	R	R	c	N	c	N	c	N	c	R	c	N	c	N
...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
20	R	R	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	10 per cent R 45 per cent R 80 per cent N	20	N	20	R	20	R	20	R
Boiling	R	R	N	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	10 per cent R 45 per cent R 80 per cent N	c	N	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	10 per cent R 45 per cent R 80 per cent N	20	N	20	R	20	R	20	R
Boiling	R	R	N	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	10 per cent R 45 per cent R 80 per cent N	c	N	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	R	20	R	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	R	c	N	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	...	....	...	....	20	R	...	....	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R												
...	..	..	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	...	....	...	....	20	R	20	R	20	V
...	..	..	..	c	R	R	R	c	R	R	R	...	..	..	..	...	..	..	..	c	N										
...	..	..	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	...	....	...	....	20	R	20	V	20	R
												...	..	..	..	...	..	..	..	c	N	...	....	...	....	c	R	c	V	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	...	....	...	....	20	R	20	R	20	R
70	R	R	R	70	R	R	R	70	R	R	R	...	..	..	..	...	..	..	..	c	N										
Boiling	R	R	R	Boiling	N	N	N	Boiling	R	R	R																				
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	...	....	20	R	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	R								
...	..	..	..	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	...	....	...	....	20	N	20	V	20	R
...	..	..	..	...	..	..	..	...	..	..	..	c	R	R	R	c	R	R	R												
...	R	N	N	...	R	R	R	...	R	R	R	15	R	R	R	...	R	R	R	...	N	...	R	...	N	...	R	...	R	...	R
...	..	..	..	...	..	..	..	...	..	..	..	80	N	N	N																
...	R	R	R	...	R	R	R	...	R	R	R	15	R	R	R	...	R	R	R	...	N	...	R	...	R	...	R	...	R	...	R
...	..	..	..	...	..	..	..	...	..	..	..	80	R	R	R																
...	R	R	R	...	R	R	R	...	R	R	R	15	R	R	R	...	R	R	R	...	N	...	R	...	R	...	R	...	R	...	R
...	..	..	..	...	..	..	..	...	..	..	..	80	R	R	R																
...	R	R	R	...	R	R	R	...	R	R	R	15	R	R	R	...	R	R	R	...	N	...	R	...	R	...	R	...	R	...	R
...	..	..	..	...	..	..	..	...	..	..	..	80	R	R	R																

PLATE VIII.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART IIb.

s																
it and etable ices	Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Temperature		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Medium			
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Stainless Iron "L".........	Latrobe Electric Steel Co.
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Regular Stainless Steel......	
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Stainless Iron "N".........	
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Lusterite Stainless Steel.....	
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Hy-Glo Stainless Steel......	
R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Stainless Iron "H".........	
N N	20 c	N N	... ...	....	20 c	R R	20 c	R R	...	....	...	....	....	....	Enduro A..................	Ludlum Steel Co.
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	Enduro S..................	
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	KM 1......................	
R R	... ...	....	... ...	....	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	KA 2......................	
R R	... ...	....	... ...	....	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	KA 2-S....................	
R R	20 c	R R	... ...	....	20 c	R R	20 c	R R	20 c	R R	j j	R R	Tartaric Acid........ SO_2[c]	....	KA 4......................	
R	20	V	...	....	20	R	20	R	20	R	...	....	....	....	V-2-A.....................	Midvale Co.
V	20	V	...	....	20	R	20	R	20	R	...	....	....	....	Nicral "C"................	
R R	20 c	V V	... ...	....	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	ATV-1.....................	
R	20	V	...	....	20	R	20	R	20	R	...	....	....	....	Midvale HR................	
R	20	V	...	....	20	R	20	R	20	R	...	....	....	....	"B. T. G".................	
R	20	V	...	....	20	R	20	R	20	R	...	....	....	....	ATV-3.....................	
R	...	....	...	....	...	....	...	....	...	....	...	N N R N N	Carbolic Acid........ Chlorsulfonic Acid... Tannic Acid (dil.)... Ferric Chloride...... Sodium Sulfate......	....	Defirust..................	Rustless Iron Corp. America
R	...	....	...	....	...	....	...	....	...	....	...	R N R R N	Carbolic Acid........ Chlorsulfonic Acid... Tannic Acid......... Sodium Sulfate...... Ferric Chloride......	....	Special Defirust...........	
R	...	....	...	....	...	....	...	....	...	....	...	R R R N R	Carbolic Acid........ Chlorsulfonic Acid... Tannic Acid......... Ferric Chloride...... Sodium Sulfate......	....	Defistain.................	
R	...	....	...	....	...	....	...	....	...	....	...	R R R N R	Carbolic Acid........ Chlorsulfonic Acid... Tannic Acid......... Ferric Chloride...... Sodium Sulfate......	....	Defiheat..................	

PLATE IX.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART III*a*

Compositions and Physical and Mechanical Properties

Universal Steel Co.
Vanadium Alloy Steel Co.
Babcock & Wilcox Tube Co.
Calorizing Co.
Duraloy Co.
Electro-Alloys Co.
General Alloys Co.
Michiana Products Corp.
Michigan Steel Casting Co.
Ohio Steel Foundry Co.
Wm. J. Sweet Foundry Co.

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Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured								Types of Service for Which Recommended					Specific Gravity	Melting Range (Liquidus and Solidus Temperatures), deg. Cent.	
			Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical	Typical Applications			Mean
Universal Steel Co.	Uniloy 2825	C 0.25, Mn 0.40, Si 0.25, Cr 28.5	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	...	7.60	...	0.00
	Uniloy 1809	C 0.10, Mn 0 40, Si 0.25, Cr 17.0	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	...	7.66	...	0.00
	Uniloy Stainless	C 0.35, Mn 0.35, Si 0.30, Cr 14.0	...	✓	✓	✓	✓	✓	...	✓	✓	...	✓	...	Cutlery	7.75	...	0.00
	Uniloy 1409	C 0.10, Mn 0.40, Si 0.25, Cr 12.75	...	✓	✓	✓	✓	✓	...	✓	✓	...	✓	...	...	7.70	...	0.00
	Uniloy Special 21-12	C 0.18, Mn 0.70, Si 1.05, Cr 21.5, Ni 11.5	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	...	7.88[c]	...	0.00
	Uniloy Special 18-8	C 0 05,[j] Mn 0.50,[b] Si 0.38, Cr 18.5, Ni 8.5	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	...	7.86[c]	...	0.00
Vanadium Alloy Steel Co.	Stainless A	C 0.33, Mn 0.30, Si 0.25, Cr 14.0	...	✓	✓	✓	✓	✓	...	✓	✓	✓	...	...	Cutlery	7.75	...	0.00
Babcock and Wilcox Tube Co.	Enduro A[h]	C 0.12,[b] Mn 0.50, Si 0.85, Cr 17.5	✓	...	...	...	...	...	✓	...	✓	✓	...	...	Condenser tubes, nitric acid and nitrating equipment, heat-resistant castings and parts	7.67	1510	0.00
	Enduro KA 2	C 0.15,[b] Mn 0.50,[b] Si 0.75,[b] Cr 18.0, Ni 8.5	✓	...	...	...	...	...	✓	...	✓	✓	...	.	Oil-cracking tubes, condenser tubes, nitric acid and nitrating equipment, dairy equipment and miscellaneous corrosion and heat-resistant structures	7.89	1455 to 1400	0.00
	No. 1100 Alloy	C 0.65,[b] Mn 0.50,[b] Si 1.85, Cr 22.0, Ni 23.0	✓	...	...	...	...	...	...	...	...	✓	...	...	Furnace rolls, grates, retorts, skid rails, discs, chains and other high temperature furnace parts	...	1415	...
	No. 1000 Alloy	C 2.35, Mn 1.50,[b] Si 2.50, Cr 18.00, W 12.00	✓	...	...	...	...	...	...	...	...	...	✓	...	Abrasion-resistant parts and faces, ceramic and cold draw dies	...	1260 to 1200	...
Calorizing Co.	Calite "A"	Ni 35.0, Cr 15.0, Fe balance	...	...	...	...	...	...	...	...	...	✓	...	...	...	7.89	...	0.000
	Calite "B"	Cr 20.0, Ni 8.00, Fe + Al balance	✓	...	...	...	...	...	...	...	...	✓	...	...	Carrying heavy loads at high temperatures	7.49	...	0.000
	Calite "N"	Ni 65.0, Cr 18.0, Fe balance	✓	...	...	...	...	...	...	...	...	✓	...	...	Furnace parts and heat treatment equipment subject to sudden temperature changes	8.10	...	0.000
Duraloy Co.	Duraloy A	Cr 28.5, Fe balance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Furnace parts, valve and fittings, rabble arms, precipitators, etc.	7.60	1455 to 1230	0.000
	Duraloy N	Cr 22.5, Ni 11.00, Fe balance	✓	...	✓	✓	✓	✓	✓	✓	✓	✓	...	...	...	7.89	1455 to 1400	0.000
Electro-Alloys Co.	Thermalloy "A"	C 0 40, Mn 1.00, Si 1.00, Cr 17.0, Ni 40.00, Fe balance	...	...	...	...	...	...	...	...	...	...	...	...	Furnace parts, carburizing boxes and retorts, cyanide pots, resistance grids, conveyor parts and pyrometer tubes	8.03	1370 to 1260	0.000
	Thermalloy "B"	C 0.80, Mn 2.00, Si 2.00, Cr 19.0, Ni 65.0, Fe balance	...	...	...	...	...	...	...	...	...	...	...	...	Furnace parts, carburizing boxes and retorts, cyanide pots, resistance grids, conveyor parts and pyrometer tubes	7.85	1370 to 1260	0.000
	Thermalloy "C"	C 0.50, Mn 0.50, Si 0.40, Cr 27.5	...	...	...	...	...	...	...	...	...	...	...	...	Annealing boxes, lead pots, rabble arms for roasting furnaces, cement chutes and pyrometer tubes where corrosive sulfur compounds are encountered at high temperatures	7.60	1400 to 1345	0.000
	Thermalloy "D"	C 0.40, Mn 0.50, Si 0.40, Cr 27.5, Ni 2.5	...	...	...	...	...	...	...	...	...	...	...	...	Annealing boxes, lead pots, rabble arms for roasting furnaces, cement chutes and pyrometer tubes where corrosive sulfur compounds are encountered at high temperatures	7.60	1400 to 1345	0.000
General Alloys Co.	Q Alloy Grade K 1	Ni 67.00, Cr 20.00, Si 1.75, Mn 1.32, C 0.50	✓	✓	✓	...	✓	✓	✓	✓	✓	✓	...	...	Carburizing containers, any parts operating to 1205° C.	8.05	1440 to 1245	0.000
	Xite	Ni 38.0, Cr 18.0, Mn 1.12, Si 2.0, C 0.50	✓	...	...	...	✓	✓	✓	...	✓	✓	...	...	Furnace parts, pots, chain, rails, retorts, general mechanism for corrosion and high temperature service	8.05	1485 to 1455	0.000
Michiana Products Corp.	Firearmor	C 0.50, Si 1.0, Mn 1.75, Cr 20.0, Ni 60.0	✓	...	...	...	✓	...	...	...	✓	✓	...	...	Furnace parts, carburizing and annealing containers, resistor elements, salt and lead pots	8.09	1330	0.000
Michigan Steel Casting Co.	Misco	C 0.50, Mn 0.70, Si 1.50, Ni 36.0, Cr 16.0, Fe balance	✓	✓	✓	✓	✓	...	✓	✓	✓	✓	✓	...	Furnace parts, carburizing and annealing containers, chain, guides	7.92	1480 to 1400	0.0000
	Misco "C"	C 0.50, Mn 0.50, Si 1.50, Cr 29.0, Ni 9.0, Fe balance	✓	...	✓	✓	✓	...	...	✓	✓	✓	✓	...	Furnace parts	7.87	1480 to 1400	0.0000
Ohio Steel Foundry Co.	Fahrite N-1	Ni 35.0, Cr 15.0, Fe balance	✓	...	✓	...	✓	...	...	...	...	✓	...	...	Carburizing containers, furnace parts, high temperature valves	8.15	...	(20 to 13 0.0000
	Fahrite CS	Cr 25.0, Fe balance	✓	...	...	...	...	...	...	...	✓	✓	...	...	Chiefly for applications to high sulfur gases at elevated temperatures	...	...	...
Wm. J. Sweet Foundry Co.	Sweetaloy 16	Cr 18.0, Fe balance	✓	...	...	...	...	...	...	...	✓	...	...	...	...	...	...	...
	Sweetaloy 17	Cr 18.0, Ni 8.0	✓	...	...	...	...	...	...	...	✓	✓	✓	...	...	...	...	...
	Sweetaloy 18	Cr 10.0, Ni 22.0	✓	...	...	...	...	...	...	...	✓	...	...	...	...	...	...	...
	Sweetaloy 19	Cr 28.0, Fe balance	✓	...	...	...	...	...	...	...	✓	...	✓	...	...	...	...	...
	Sweetaloy 20	Cr 18.0, Ni 36.0	✓	...	...	...	...	...	...	...	...	✓	...	...	...	...	...	...
	Sweetaloy 21	Cr 15.0, Ni 65.0	✓	...	...	...	...	...	...	...	...	✓	...	...	...	...	...	...
	Sweetaloy 22	Cr 28.0, Ni 10.0	✓	...	...	...	...	...	...	...	✓	✓	✓	...	...	...	...	...

[a] Annealed.

[b] Maximum.

[c] Approximate.

[g] Hardened

[h] Tubes C = 0.12

PART III*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PRO

Physical Properties								Mechanical Properties at Room Temperature															
Coefficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Form for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion),
Mean 0 to 100° C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.				
0.0000120[c]	....	0.064[c]	....	0.142	......	67.0	....	Hot rolled bars	80 000 to 100 000	55 000 to 75 000	......	30.0 to 10.0	50.0 to 20.0	......	160 to 228	....	....	....	....	....	......	....	....
0.0000121	....	0.080[c]	....	0.155	......	59.8	....	Hot rolled bars	42 000 to 63 000	72 000 to 90 000	......	35.0 to 25.0	70.0 to 55.0	......	150 to 210	....	....	....	....	....	......	....	....
0.0000121[c]	....	0.046[c]	....	0.120	......	60.0	....	Hot rolled bars	98 000 to 268 000	65 000 to 230 000	......	30.0 to 3.0	60.0 to 5.0	......	163 to 569	....	....	....	....	....	......	....	....
0.0000121[c]	....	0.088	....	0.140	......	59.0	....	Hot rolled bars	70 000 to 190 000	40 000 to 165 000	......	40.0 to 10.0	78.0 to 30.0	......	140 to 3 90	....	....	....	....	....	......	....	....
0.0000162	....	0.048[c]	....	0.130	......	74.8	....	Hot rolled bars	95 000 to 130 000	40 000 to 105 000	......	65.0 to 32.0	70.0 to 50.0	......	160 to 260	....	....	....	....	....	......	....	....
0.0000169	....	0.064[c]	....	0.116	......	74.8	....	Hot rolled bars[e]	90 000 to 125 000	35 000 to 80 000	......	60.0 to 38.0	65.0 to 50.0	......	135 to 255	....	....	....	....	....	......	....	....
								Plates and sheets[e]	85 000 to 125 000	30 000 to 85 000	......	60.0 to 30.0	65.0 to 40.0	......	130 to 250	....	....	....	....	....	......	....	....
0.0000109	....	0.054	....	....	......	79.4	....	Hot rolled bars[g]	195 500	170 500	......	10.2	32.7	30 000 000	370	....	....	....	....	....	......	....	....
0.0000108	....	0.054[c]	....	....	......	62.5	(500 to 1000° C.) 80.0	Castings	75 000 to 110 000	45 000 to 60 000	......	10.0 min.	22.0 to 19.0	......	170 to 190	"B" 82.0 to 92.0	....	....	....	....	......	....	....
								Tubes	70 000 to 90 000	45 000 to 60 000	......	35.0 to 25.0	70.0 to 50.0	......	145 to 160	"B" 80.0 to 90.0	....	....	....	....	......	....	....
0.0000158	(20 to 565° C.) 0.0000166	....	(110 to 385° C.) 0.043 (260 to 385° C.) 0.044	0.118	......	73.0	(100 to 800° C.) 104.0	Casting	70 000 to 80 000	26 000 to 40 000	15 000 to 30 000	75.0 to 40.0	75.0 to 40.0	27 500 000	130 to 170	....	....	40 to 80	....	70 000 to 80 000	26 000 to 40 000	15 000 to 30 000	....
								Tubes	85 000	26 000	15 000	50.0	40.0	27 500 000	135	....	....	75	....	85 000	26 000	15 000	....
....	....	....	....	....	......	90.0	....	Castings	60 000	40 000	......	75.0 to 10.0	....	......	....	"B" 83.0 to 89.0	....	....	....	....	......	....	....
....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	600 to 680	....	....	....	....	....	......	....	....
0.000009	....	0.027	....	....	......	....	....	Castings	70 000	......	......	1.5	2.0	......	230	....	....	....	....	....	......	....	....
0.000009	....	0.027	....	....	......	....	....	Castings	63 000	......	......	0	0	......	340	....	....	....	....	....	......	....	....
0.0000162	....	0.033	....	....	......	....	....	Castings	50 000	......	......	2.0	2.0	......	170	....	....	....	....	....	......	....	....
0.0000102	(0 to 1000° C.) 0.0000133	0.080[c]	....	0.15	(20 to 600° C.) 0.165	64.0	....	Castings	40 000 to 50 000	30 000 to 40 000	......	1.0 to 0	2.0 to 0	......	....	....	....	....	....	....	......	....	
								Hot rolled bars	80 000 to 90 000	60 000 to 65 000	......	27.0 to 10.0	45.0 to 15.0	......	160 to 210	....	....	....	5.0[b]	....	......	....	
0.0000162	(20 to 1000° C.) 0.0000202	0.054[c]	....	....	(35 to 1000° C.) 0.142	75.6	....	Hot rolled bars	105 000 to 115 000	55 000 to 80 000	......	45.0 to 35.0	65.0 to 50.0	29 500 000	200 to 260	....	....	....	....	....	......	....	
0.0000164	....	0.012	....	0.112	......	112.0	....	Castings	65 000	50 000	......	2.0 to 1.0	2.0 to 1.0	......	241	....	25.0 to 35.0	....	....	....	......	....	
0.0000164	....	0.012	....	0.112	......	112.0	....	Castings	65 000	50 000	......	2.0 to 1.0	2.0 to 1.0	......	241	....	25.0 to 35.0	....	....	....	......	....	
0.0000153	....	0.019	....	0.112	(650° C.) 0.212 (870° C.) 0.145	....	....	Castings	50 000	40 000	......	1.0	2.0 to 1.0	......	196	25.0 to 28.0	25.0 to 30 0	....	....	....	......	....	
						....	....	Hot rolled bars	124 000	88 000	......	8.0	5.0	......	286	35	35.0 to 40.0	....	....	....	......	....	
0.0000153	....	0.019	....	0.112	(650° C.) 0.212 (870° C.) 0.145	....	....	Castings	50 000	40 000	......	1.0	2.0 to 1.0	......	196	25.0 to 28.0	35.0 to 30 0	....	....	....	......	....	
						....	....	Hot rolled bars	132 000	96 000	......	30.0	30.0	......	302	32.0 to 34.0	35.0 to 40.0	....	....	....	......	....	
0.0000128	....	0.014	....	0.114	......	....	....	Hot rolled bars	110 000 to 120 000	85 000 to 90 000	50 000 to 55 000	28.0	45.0	......	....	....	....	....	....	....	......	....	9
0.0000124	....	0.014	....	0.114	......	....	....	Castings	65 000 to 70 000	53 000 to 56 000	46 000 to 48 000	2.5	4.0	......	....	....	....	....	....	....	......	....	4
0.0000119	(0 to 815° C.) 0.0000140	0.033	....	0.112	(0 to 815° C.) 0.126	124.0	....	Castings	60 000	46 000	......	1.2	2.9	......	200	....	27.0	....	....	....	......	....	
								Plates and sheets	100 000	60 000	......	8.5	12.8	......	....	....	....	....	....	....	......	....	
0.0000135	....	0.0247	....	....	......	118.0	....	Hot rolled bars	97 000	......	23 000	51.0	42.0	......	235 to 245	....	33.0 to 35.0	....	....	....	......	....	
								Castings	66 000	......	18 000	6.0	3.0	......	180 to 190	....	25.0 to 28.0						
0.0000135	....	0.0247	....	....	......	....	....	Castings	82 600	......	......	1.0	0.8	......	215 to 218	....	....	....	....	....	......	....	
								Hot rolled bars	130 000	105 000	......	25.0	34.0	......	....	....	....	....	....	....	......	....	
(20 to 130° C.) 0.0000114	(20 to 995° C.) 0.0000172	0.031	....	0.110	......	....	....	Castings	50 000	......	24 000	1.5	1.5	......	171 to 180	"B" 87 to 90	....	....	....	200 000	......	37 000	
....	....	....	....	....	......	....	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	75 000	50 000	......	10.0	15.0	......	200	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	84 200	42 100	......	47.0	42.0	......	165	....	....	....	75.0	....	......	....	
....	....	....	....	....	......	....	....	Castings	79 000	46 500	......	23.0	24.0	......	150	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	50 000	35 000	......	2.0	3.0	......	170	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	64 200	41 200	......	7.0	7.8	......	165	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	62 000	48 000	......	4.0	3.0	......	170	....	....	....	....	....	......	....	
....	....	....	....	....	......	....	....	Castings	70 000	59 500	......	3.0	2.5	......	200	....	....	....	....	....	......	....	

= 0.12 maximum. Castings, C = 0.25 maximum

[i] Design stress ¼ values given.

[j] C = 0.05. Maximum C = 0.25.

RT III*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																			Mechanical Properties at Elevated Temperatures				
						Hardness Number			Impact Strength														
Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.	Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination
80 000 to 100 000	55 000 to 75 000	......	30.0 to 10.0	50.0 to 20.0	......	160 to 228	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
42 000 to 63 000	72 000 to 90 000	......	35.0 to 25.0	70.0 to 55.0	......	150 to 210	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
98 000 to 265 000	65 000 to 230 000	......	30.0 to 3.0	60.0 to 5.0	......	163 to 569	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
70 000 to 190 000	40 000 to 165 000	......	40.0 to 10.0	78.0 to 30.0	......	140 to 3 90	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
95 000 to 130 000	40 000 to 105 000	......	65.0 to 32.0	70.0 to 50.0	......	160 to 260	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
90 000 to 125 000	35 000 to 80 000	......	60.0 to 38.0	65.0 to 50.0	......	135 to 255	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
85 000 to 125 000	30 000 to 85 000	......	60.0 to 30.0	65.0 to 40.0	......	130 to 250	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....		
195 500	170 500	......	10.2	32.7	30 000 000	370	....	....	....	....	....	......	....	....	......	....	......	....	....	650 760 850	8 000 5 500 2 000	....	Recommended
75 000 to 110 000	45 000 to 60 000	......	10.0 min.	22.0 to 19.0	......	170 to 190	"B" 82.0 to 92.0	....	....	....	....	......	....	....	......	....	......	....	....	540 595	7 000 4 500	1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests Time duration of
7 000 to 90 000	45 000 to 60 000	......	35.0 to 25.0	70.0 to 50.0	......	145 to 160	"B" 80.0 to 90.0	....	....	....	....	......	....	....	......	....	......	....	....	650 735	1 600 900[j]	1 per cent in 100 000 hours 1 per cent in 100 000 hours	tests 400 to 4000 hours
70 000 to 80 000	26 000 to 40 000	15 000 to 30 000	75.0 to 40.0	75.0 to 40.0	27 500 000	130 to 170	....	....	40 to 80	....	70 000 to 80 000	26 000 to 40 000	15 000 to 30 000	....	......	....	......	....	....	540 595	15 000 8 000	1 per cent in 100 000 hours 1 per cent in 100 000 hours	Long time tests Time duration of
85 000	26 000	15 000	50.0	40.0	27 500 000	135	....	....	75	....	85 000	26 000	15 000	....	......	....	......	....	....	650 815	5 500 750[j]	1 per cent in 100 000 hours 1 per cent in 100 000 hours	test 400 to 4000 hours
60 000	40 000	......	75.0 to 10.0	....	......	....	"B" 83.0 to 89.0	....	....	....	....	......	....	....	......	....	......	....	....	980 1035 1095	1 450 1 160 870	....	Recommended
......	......	......	....	....	......	600 to 680	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
70 000	......	......	1.5	2.0	......	230	....	....	....	....	....	......	....	....	......	....	......	....	....	650 705 760 815 870 925 980 1095	3 800 3 300 2 500 2 000 1 700 1 500 1 250 1 250	....	25 per cent of yield point
63 000	......	......	0	0	......	340	....	....	....	....	....	......	....	....	......	....	......	....	....	540 595 650 705 760 815 870 925 980	11 000 9 000 7 000 5 500 4 500 3 800 3 000 2 500 2 000	....	25 per cent of yield point
50 000	......	......	2.0	2.0	......	170	....	....	....	....	....	......	....	....	......	....	......	....	....	650 705 760 815 870 925 980 1095	4 500 4 000 3 500 3 000 2 500 2 000 1 250 1 250	....	25 per cent of yield point
40 000 to 50 000	30 000 to 40 000	......	1.0 to 0	2.0 to 0	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
80 000 to 90 000	60 000 to 65 000	......	27.0 to 10.0	45.0 to 15.0	......	160 to 210	....	....	....	5.0[b]	....	......	....	....	......	....	......	....	....	....	....		
105 000 to 115 000	55 000 to 80 000	......	45.0 to 35.0	65.0 to 50.0	29 500 000	200 to 260	....	....	....	....	....	......	....	....	......	....	11 200 000	....	....	....	....	....	....
65 000	50 000	......	2.0 to 1.0	2.0 to 1.0	......	241	....	25.0 to 35.0	....	....	....	......	....	....	......	....	......	....	....	980	1 000	....	Recommended
65 000	50 000	......	2.0 to 1.0	2.0 to 1.0	......	241	....	25.0 to 35.0	....	....	....	......	....	....	......	....	......	....	....	980	1 000	....	Recommended
50 000	40 000	......	1.0	2.0 to 1.0	......	196	25.0 to 28.0	25.0 to 30 0	....	....	....	......	....	....	......	....	......	....	....	870	500	....	Recommended
124 000	88 000	......	8.0	5.0	......	286	35	35.0 to 40.0	....	....	....	......	....	....	......	....	......	....	....	....	....		
50 000	40 000	......	1.0	2.0 to 1.0	......	196	25.0 to 28.0	35.0 to 30.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
132 000	98 000	......	30.0	30.0	......	302	32.0 to 34.0	35.0 to 40.0	....	....	....	......	....	....	......	....	......	....	....	....	....		
110 000 to 120 000	85 000 to 90 000	50 000 to 55 000	28.0	45.0	......	....	....	....	....	....	....	......	....	91 000	20 400	190.0	12 400 000	....	....	....	....	....	....
65 000 to 70 000	53 000 to 56 000	46 000 to 48 000	2.5	4.0	......	....	....	....	....	....	....	......	....	47 100	22 100	4.5	7 970 000	....	....	....	....	....	....
60 000	46 000	......	1.2	2.9	......	200	....	27.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
100 000	60 000	......	8.5	12.8	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....		
97 000	......	23 000	51.0	42.0	......	235 to 245	....	33.0 to 35.0	....	....	....	......	....	....	......	....	......	....	....	815 870 925 980 1040 1095	800 530 350 230 175 150	....	Short time tests
66 000	......	18 000	6.0	3.0	......	180 to 190	....	25.0 to 28.0															
82 600	......	......	1.0	0.8	......	215 to 218	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
130 000	105 000	......	25.0	34.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....		
50 000	......	24 000	1.5	1.5	......	171 to 180	"B" 87 to 90	....	....	....	200 000	......	37 000	....	......	....	......	....	....	595 705 815 870 980 1095	9 800 5 500 3 500 1 500 350 150	....	Recommended
......	......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
75 000	50 000	......	10.0	15.0	......	200	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
84 200	42 100	......	47.0	42.0	......	165	....	....	....	75.0	....	......	....	....	......	....	......	....	....	....	....	....	....
79 000	46 500	......	23.0	24.0	......	150	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
50 000	35 000	......	2.0	3.0	......	170	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
64 200	41 200	......	7.0	7.8	......	165	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
2 000	48 000	......	4.0	3.0	......	170	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....
0 000	59 500	......	3.0	2.5	......	200	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....

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given.

[j] C = 0.05. Maximum C = 0.25.

PLATE IX.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART III*a*.

es	Fabricating Properties														Trade Name of Alloy	Manufacturer
ethod of Stress rmination	Machining	Hot Working		Cold Working	Welding					Brazing	Soldering	Precautions to be Observed				
		Optimum Temperature Range, deg. Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance			In Design	In Fabricating	In Use		
....	Slightly tougher than tool steel	870 to 1150	....	......	..	✓	✓	✓	✓	..	..	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy 2825............	Universal Steel Co.
....	Machines readily	790 to 1095	....	......	..	✓	✓	✓	✓	..	..	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy 1809............	
....	Similar to tool steel	955 to 1150	....	......	..	✓	✓	✓	✓	..	..	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy Stainless........	
....	Machines readily	870 to 1150	....	......	..	✓	✓	✓	✓	..	..	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy 1409............	
....	Somewhat more difficult than tool steel	955 to 1175	....	......	..	✓	✓	✓	✓	✓	✓	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy Special 21–12.....	
....	Somewhat more difficult than tool steel	870 to 1205	....	......	..	✓	✓	✓	✓	✓	✓	Refer to manufacturer for details covering conditions and applications	....	....	Uniloy Special 18–8......	
mended	With some difficulty	925 to 1150	....	......	..	✓	..	..	..	✓	..	....	....	....	Stainless A............	Vanadium Alloy Steel Co.
ime tests uration of 400 to hours	Machines like 0.40 per cent carbon steel	1010 to 1150	....	......	..	✓	..	✓	✓	✓	✓	Avoid sharp changes in section in castings	Subject to grain growth at high temperatures	Not recommended for continuous operation from 205 to 565° C.	Enduro A^h............	Babcock & Wilcox Tube Co.
me tests uration of 400 to hours	Tougher than ordinary steels	1065 to 1260	....	......	..	✓	..	✓	✓	✓	✓	....	Welds and cold worked parts should be heat treated	Avoid heat and cooling in high temperature use	Enduro KA 2............	
mended	Machines readily	....	....	......	..	✓	..	✓	..	..	..	Use uniform sections in design of castings	....	....	No. 1100 Alloy..........	
....	Not machineable	....	....	......	..	✓	..	✓	..	..	..	Castings should have uniform section	....	Avoid shocks	No. 1000 Alloy..........	
cent of point	Readily machined	....	....	......	..	✓	..	✓	..	..	..	....	....	....	Calite "A"............	Calorizing Co.
cent of point	Not machineable	....	....	......	..	✓	..	..	..	..	..	....	....	....	Calite "B"............	
cent of point	Readily machined	....	....	......	..	..	..	✓	..	..	..	....	....	....	Calite "N"............	
......	Same as 50 per cent carbon steel	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Duraloy A..	Duraloy Co.
......	Somewhat difficult	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Duraloy N.............	
ended	With slower speed and feed, similar to C-steel 240 Br.	1150	....	......	..	✓	..	✓	✓	..	..	Use uniform sections with large fillets	....	Heat and cool uniformly. Avoid extreme temperature changes	Thermalloy "A"........	Electro-Alloys Co.
ended	With slower speed and feed, similar to C-steel 240 Br.	1150	....	......	..	..	..	..	..	..	..	Use uniform sections with large fillets	....	Heat and cool uniformly. Avoid extreme temperature changes	Thermalloy "B"........	
ended	Readily machineable	1095	....	......	..	..	..	..	..	..	..	Use uniform sections with large fillets	....	Avoid rapid changes in temperature	Thermalloy "C"........	
......	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Thermalloy "D"........	
.....	Same as annealed high speed	1095 to 1120	Soak thoroughly, reheat frequently	......	..	✓	..	✓	..	..	..	Allowances to be made for influence of loading temperatures, heat sources, etc.	Use welded joints	....	Q Alloy, Grade K 1......	General Alloys Co.
.....	Much as high speed steel	1095 to 1120	Soak thoroughly, reheat frequently	......	..	✓	..	✓	..	..	..	Consideration of temperatures, influence of loading, heat sources, etc.	Use welded joints	....	Xite..................	
.....	Satisfactory at slow speeds and feeds	....	....	......	..	✓	✓	✓	..	✓	✓	Avoid forms that promote shrinkage difficulties; consider stresses as to temperature changes	....	Temperature variations and rate of change; also furnace atmosphere important	Firearmor..............	Michiana Products Corp.
e tests	....	....	....	......	..	✓	✓	✓	..	..	..	....	....	....	Misco..................	Michigan Steel Casting Co.
.....	....	....	....	......	..	✓	..	✓	..	..	..	....	....	....	Misco "C"..............	
nded	Slow speeds—heavy cut	....	....	......	..	✓	..	✓	..	..	..	....	....	....	Fahrite N-1............	Ohio Steel Foundry Co.
.....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Fahrite CS.............	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 16...........	Wm. J. Sweet Foundry Co.
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 17...........	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 18...........	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 19...........	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 20...........	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 21...........	
....	....	....	....	......	..	..	..	..	..	..	..	....	....	....	Sweetaloy 22...........	

PLATE X.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART III*b*

Corrosion-Resistant Properties

Universal Steel Co.
Vanadium Alloy Steel Co.
Babcock & Wilcox Tube Co.
Calorizing Co.
Duraloy Co.
Electro-Alloys Co.
General Alloys Co.
Michiana Products Corp.
Michigan Steel Casting Co.
Ohio Steel Foundry Co.
Wm. J. Sweet Foundry Co.

R = Recommended. N = Not recommended. V = Varies with individual conditions; consult manufacturer.

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																						
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydrocarbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen		Chlorine		Hydro Acid
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation
Universal Steel Co.	Uniloy 2825	1150	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Uniloy 1809	900	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Uniloy Stainless	595	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Uniloy 1409	595	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Uniloy Special 21–12	1150	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Uniloy Special 18–8	925	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Vanadium Alloy Steel Co.	Stainless A	815	....	....	....	815	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Babcock & Wilcox Tube Co.	Enduro A	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	....	....	....
	Enduro KA 2	925	....	925	....	925	....	760	....	925	....	870	....	....	....	....	....	....	....	925	....	....	....	....
	No. 1100 Alloy	1150	....	1150	....	1095	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Calorizing Co.	Calite "A"	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	....	....	....	....	....	....	....	....	....	....	....
	Calite "B"	980	....	980	....	980	....	980	....	980	....	980	....	....	....	....	....	....	....	....	....	....	....	....
	Calite "N"	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	....	....	....	....	....	....	....	....	....	....	....
Duraloy Co.	Duraloy A	1150	....	1150	....	....	....	980	....	1150	....	980	....	1150	....	1150	....	1150	[i]	....	....	....	....	....
	Duraloy N	1150	....	1150	....	....	....	980	....	1150	....	980	....	....	....	....	....	....	....	....	....	....	....	....
Electro-Alloys Co.	Thermalloy "A" and "B"	1095	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Thermalloy "C" and "D"	1095	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
General Alloys Co.	Q Alloy Grade K 1	1205	....	1205	....	1205	....	1205	....	1205	...	1205	....	....	....	....	....	....	....	....	....	....	....	....
	Xite	1010	....	1010	....	1010	....	1010	....	1010	...	1010	....	....	....	....	....	....	....	....	....	....	....	....
Michiana Products Corp.	Firearmor	1095 to 1260	....	1095 to 1260	....	1095 to 1260	....	1095 to 1260	....	1095 to 1260	....	1095 to 1260	....	....	....	....	....	....	....	....	....	....	....	....
Michigan Steel Casting Co.	Misco	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Misco "C"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Ohio Steel Foundry Co.	Fahrite N-1	1095	....	1095	....	1095	....	955	....	955	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Fahrite CS	925	....	925	....	....	....	....	....	....	....	....	....	925	....	925	....	925	....	....	....	....	....	....
Wm. J. Sweet Foundry Co.	Sweetaloy 16	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	870	....	....	....	....
	Sweetaloy 17	925	....	925	....	925	....	925	....	925	....	925	....	925	....	925	....	925	....	925	....	....	....	....
	Sweetaloy 18	980	....	980	....	980	....	980	....	980	....	980	....	980	....	980	....	980	....	980	....	....	....	....
	Sweetaloy 19	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	1035	....	....	....	....
	Sweetaloy 20	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	1095	....	....	....	....
	Sweetaloy 21	1150	....	1150	....	1150	....	1150	....	1150	....	1150	....	1150	....	1150	....	1150	....	1150	....	....	....	....
	Sweetaloy 22	1205	....	1205	....	1205	....	1205	....	1205	....	1205	....	1205	....	1205	....	1205	....	1205	....	....	....	....

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[a] Consult manufacturer. [c] Above room temperature. [d] Hardened. [f] 40 per cent concentrated, maximum. [g] Under spec

PART III*b*. CORROSION-RESISTANT PROPERTIE

Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia		Fused Caustic Alkalis		Fused Chlorides		Form of Material	Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines		
Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.		Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution
....	....	....	....	....	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
....	....	....	....	....	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	V	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	V	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	R	*c*	R	R	N	*c*	N	N
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	..	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	R	*c*	R	R	*f*	*c*	R	R	R	*c*	R	R	R	*c*	R	R
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									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	V	V	V	*c*	..	R	..	*c*	R	R	R	*c*	R	R	R	...	..	..
....	....	1150	....	....	....	....	....	....	20	V	V	V	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	..	..
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....	....	1095	....	1010	*g*	1010	*g*	**Cast**	20	N	N	V	20	R	R	V	20	V	V	V	20	R	..	V	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
									c	N	N	V	*c*	R	R	V	*c*	V	V	V	*c*	R	..	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
....	....	1010	....	900	*a*	900	*a*	....	20	N	N	V	20	R	R	V	20	V	V	V	20	R	..	V	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
									c	N	N	V	*c*	R	R	V	*c*	V	V	V	*c*	R	..	V	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
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									c	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	...	..	..	..	*c*	R	R	R	*c*	R	R	R	...	..	..
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....	....	....	....	....	....	....	....	....	...	R	R	V	...	..	N	..	...	..	..	..	...	R	R	R	...	..	..	..	...	..	..	..	...	R	R	R	...	..	..
....	....	....	....	....	....	955	....	....	20	N	V	R	20	N	N	N	20	N	N	N	20	..	..	R	20	N	N	N	20	R	R	R	20	R	R	R	...	..	..
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....	....	870	....	870	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	N	N	R	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	R	R	R	...	..	..
....	....	925	....	925	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	..	..
....	....	980	....	980	....	....	....	....	20	R	..	..	20	N	N	N	20	N	N	N	20	N	N	N	20	R	..	..	20	N	N	N	20	R	R	R	...	..	..
													c	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	R	..	..	*c*	N	N	N	*c*	R	R	R	...	..	..
....	....	1035	....	1035	....	....	....	....	20	N	N	N	20	R	R	R	20	N	N	N	20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..
									c	N	N	N	*c*	R	R	R	*c*	N	N	N	*c*	N	N	N	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	..	..
....	....	1095	....	1095	....	....	....	....	20	R	R	R	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	R	R	R	...	..	..
									c	R	R	R	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	*c*	N	N	N	...	..	..	..	...	..	..
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....	....	1205	....	1205	....	....	....	....	20	..	N	..	20	R	R	R	20	..	N	..	20	R	R	R	20	R	..	R	20	R	..	R	20	R	R	R	...	..	..
									c	..	N	..	*c*	R	R	R	*c*	..	N	..																			

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er special conditions.

[f] Dry.

PART III*b*. CORROSION-RESISTANT PROPERTIES.

												Corrosion in Media at Moderate Temperatures																			
Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	V	20	R	20	R	20	R
c	R	R	V	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	R	c	V	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	N	20	R	20	V	20	R
c	R	R	V	c	R	R	R	c	R	R	R	c	R	R	V	c	R	R	V	c	N	c	V	c	N	c	R	c	V	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	V	20	R	20	V	20	R
c	R	R	V	c	R	R	R	c	R	R	R	c	R	R	V	c	R	R	V	c	N	c	V	c	V	c	R	c	V	c	R
20	R	R	V	20	R	R	R	20	R	R	R	20	R	R	V	20	V	V	V	20	N	20	V	20	N	20	R	20	V	20	R
c	V	V	V	c	R	R	R	c	R	R	R	c	V	V	V	c	V	V	V	c	N	c	V	c	N	c	R	c	V	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	V	20	R	20	R	20	R
c	R	R	V	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	V	c	V	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	V	20	R	20	R	20	R
c	R	R	V	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	V	c	V	c	R	c	R	c	R
20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	N	20	N	R	R	...	....	20	R (saturated)	20	N	20	V	20	R	20	R
c	R	R	R	c	N	N	N	c	R	R	R	c	R	R	N	c	N	N	R	...	....	c	R (saturated)	c	N	c	V	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	...	....	20	R	20	R	20	R
c	R	R	..	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	R	...	....	c	R	c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	N	20	R	20	R	20	R
c	R	R	R	c	R	R	/.	c	R	R	R	c	R	R	R	c	R	R	R	c	N	Boiling	R (80 percent)	c	N	c	R	c	R	c	R
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c	V	V	V	c	R	R	R	c	..	R	..	c	R	R	R	...	..	..	..	c	N	c	V	c	N			c	R	c	R
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	N	20	R	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	...	..	..	..	c	N	c	R	c	N	c	R	c	R	c	R
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20	R	..	V	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	N	20	RV	20	RV	...	....
c	R	..	V	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	V	c	N	c	RV	c	RV	...	....
20	R	..	V	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	V	20	V	20	RV	20	RV	...	....
c	R	..	V	c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	c	N	c	V	c	V	c	RV	c	RV	...	....
20	N	N	N	...	..	..	..	20	R	R	R	20	R	R	R	...	..	..	..	20	N	...	....	20	N	20	V	...	....	20	R
c	N	N	N	...	..	..	..	c	R	R	R	c	R	R	R	...	..	..	..	c	N	...	....	c	N	c	V	...	....	c	R
...	R	R	R	...	..	..	..	...	..	..	..	...	R	R	R	...	..	..	..	...	N	...	....	...	....	...	V	...	R	...	V
...	R	R	R	...	..	..	..	...	..	..	..	...	R	R	R	...	..	..	..	...	N	...	....	...	....	...	R	...	R	...	V
20	..	..	R	20	N	N	N	20	R	R	R	20	R	R	R	...	..	..	..	20	N	20	N	20	N	20	N	20	N	20	R
...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	20	R	...	....	...	....
20	N	N	R	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..	..	20	N	20	N	20	N	20	R	20	V	20	V
c	N	N	N	c	N	N	N	c	N	N	N	c	R	R	R	...	..	..	..	...	....	...	....	c	N	c	R	...	....	...	....
20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..	..	20	N	20	V	20	N	20	R	20	R	20	R
c	R	R	R	c	R	R	R	c	R	R	R	c	R	R	R	...	..	..	..	...	....	...	....	c	N	c	R	c	R	c	R
20	N	N	N	20	R	..	..	20	N	N	N	20	R	R	R	...	..	..	..	20	N	20	N	20	N	20	N	20	V	20	V
c	N	N	N	c	R	..	..	c	N	N	N	c	R	R	R	...	..	..	..	...	....	...	....	c	N	c	N	...	....	...	....
20	N	N	N	20	R	R	R	20	R	R	R	20	R	R	R	...	..	..	..	20	N	20	R	20	N	20	R	20	V	20	V
c	N	N	N	c	R	R	R	c	R	R	R	c	R	R	R	...	..	..	..	...	....	c	V	c	N	c	R	c	V	c	V
20	N	N	N	20	N	N	N	20	N	N	N	20	R	R	R	...	..	..	..	20	N	20	N	20	N	20	R	20	V	20	V
c	N	N	N	c	N	N	N	c	N	N	N	...	..	..	..	...	..	..	..	...	....	...	....	...	....	c	R				
...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
20	R	R	R	20	R	..	R	20	R	..	R	20	R	R	R	...	..	..	..	20	N	20	N	20	N	20	R	20	V	20	V

PLATE X.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART III*b*.

es																
uit and getable uices	Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Temperature		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Medium			
R R	20 c	R R	20 c	V V	20 c	R R	20 c	R R	20 c	V V	...	....	....	....	Uniloy 2825	Universal Steel Co.
R R	20 c	R R	20 c	V V	20 c	R R	20 c	R R	20 c	V V	...	....	....	....	Uniloy 1809	
R R	20 c	R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	Uniloy Stainless	
R R	20 c	V V	20 c	N N	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Uniloy 1409	
R R	20 c	R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	Uniloy Special 21-12	
R R	20 c	R R	20 c	V V	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	Uniloy Special 18-8	
R R	20 c	V V	20 c	N N	20 c	R R	20 c	R R	20 c	N N	...	....	....	Any form	Stainless A	Vanadium Alloy Steel Co.
R R	20 c	R R	... ...	....	20 c	R R	20 c	R R	20 c	R R	...	....	....	All forms	Enduro A	Babcock & Wilcox Tube Co.
R R	20 c	R R	... ...	....	20 c	R R	20 c	R R	20 c	R R	...	....	....	All forms	Enduro KA 2	
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	No. 1100 Alloy	
N	...	N	...	N	...	N	...	N	...	N	...	....	....	....	Calite "A"	Calorizing Co.
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	Calite "B"	
N	...	N	...	N	...	N	...	N	...	N	...	....	....	....	Calite "N"	
R R	20 c	V V	20 ...	R	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	Duraloy A	Duraloy Co.
R R	20 c	V V	20 ...	R	20 c	R R	20 c	R R	20 c	R N	...	....	....	....	Duraloy N	
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	Thermalloy "A" and "B"	Electro-Alloys Co.
R	...	....	...	....	...	....	...	....	20	R	...	....	....	....	Thermalloy "C" and "D"	
....	20 c	V V	... ...	....	20 c	R R	20 c	R N	20 c	RV	...	....	....	Cast	Q Alloy Grade K-1	General Alloys Co
....	... ...	....	... ...	....	20 c	R R	20 c	R R	20 c	R RV	...	....	....	....	Xite	
R R	... ...	....	... ...	....	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Firearmor	Michiana Products Corp
V	...	....	...	....	...	R	...	R	...	V	...	R R R	Molten Pb. Molten Zn. Molten Sn.	....	Misco	Michigan Steel Casting Co.
V	...	....	...	....	...	R	...	R	...	V	...	R R	Molten Zn. Molten Sn.	....	Misco "C"	
R	20	V	20	R	20	R	20	R	20	N	...	....	....	....	Fahrite N-1	Ohio Steel Foundry Co.
....	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Fahrite CS	
V	20 ...	N	20 ...	V	20 ...	R	20 ...	R	20 c	N N	...	....	....	....	Sweetaloy 16	Wm. J. Sweet Foundry Co.
R R	20 ...	N	... ...	....	20 c	R R	20 c	R R	20 c	R R	...	....	....	....	Sweetaloy 17	
V	20 ...	N	20 ...	V	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Sweetaloy 18	
V V	20 ...	N	... ...	....	20 c	R R	20 c	R R	20 c	N N	...	....	....	....	Sweetaloy 19	
V	20	N	...	....	20	R	20	R	20	N	...	....	....	....	Sweetaloy 20	
....	...	....	...	....	...	....	...	....	...	....	...	....	....	....	Sweetaloy 21	
V	20	N	...	....	20	R	20	R	20	R	...	....	....	....	Sweetaloy 22	

PLATE XI.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART IV*a*

Compositions and Physical and Mechanical Properties

Driver-Harris Co.

Haynes Stellite Co.

Burgess-Parr Co.

Curtis Bay Copper and Iron Works

International Nickel Co.

Westinghouse Electric & Manufacturing Co.

Aluminum Co. of America

Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured								Types of Service for Which Recommended						
			Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical	Typical Applications	Specific Gravity	Melting Range (Liquidus and Solidus Tempera-
Driver-Harris Co.	Nichrome IV (Karma)	Ni 80.0, Cr 20.0	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	✓	High temperature electrical devices	8.5	1320
	Nichrome	C 0.12, Ni 60.0, Cr 15.0, Fe balance	...	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	✓	Pickling machine parts, valves, annealing pots, rheostats, heating units	8.15	1350
	Nichrome	C 0.80, Ni 60.0, Cr 15.0, Fe balance	✓	...	...	...	...	...	...	...	✓	✓	...	✓	Dipping baskets, carburizing boxes, retorts, heavy resistors, cyanide and lead pots, glass rolls, pyrometer tubes, furnace parts	8.06	1260
	Chromax	Ni 35.0, Cr 15.0, Fe balance	✓	...	...	...	...	...	...	...	✓	✓	...	✓	...	8.15	1480
	No. 193 Alloy	Ni 30.0, Cr 2.0, Fe balance	...	✓	...	...	✓	...	...	✓	...	✓	...	✓	Low temperature heating devices, heavy duty rheostats	8.15	......
	Invar	Ni 36.5, Fe balance	...	...	...	...	✓	...	✓	✓	...	...	...	...	Thermostats, measuring devices using low coefficient of linear expansion, struts in Bohnite pistons	8.25	......
	Grade "A" Nickel	...	..	..	...	...	✓	...	...	✓	...	...	...	✓	Incandescent lamps and radio tubes	8.9	1450
	Advance (Ideal)	Ni 45.0, Cu 55.0	...	...	...	...	✓	...	..	✓	...	✓	...	✓	Rheostats, resistance spools, thermocouples	8.9	......
	Manganin	Ni 4.0, Mn 12.0, Cu 84.0	...	...	...	...	✓	...	...	✓	...	...	...	✓	Instrument shunts, resistance standards	8.15	......
Haynes Stellite Co.	Haynes Stellite No. 1	Co 50.0, Cr 30.0, W 15.5	✓	...	..	...	...	...	...	...	✓	...	✓	...	Coating surface for grinding, crushing and conveying equipment, agriculture ploughs, bearing surfaces, dies	8.59	1250
	Haynes Stellite No. 6	Co 65.0, Cr 30.0, W 4.0	✓	✓ k	✓	...	✓	...	...	...	✓	...	✓	...	Coating surfaces and edges for dies, etc	8.38	1260
	Haynes Stellite No. 12	Co 60.0, Cr 30.0, W 8.0	✓	...	...	...	...	...	...	...	✓	...	✓	...	Same as No. 1, but has greater strength and ductility	8.40	1260
	Hascrome	Cr 12.0, Mn 3.5, Fe balance	...	...	...	...	...	...	...	✓	...	...	✓	...	For moderately severe abrasion, filler for worn parts preparatory to stelliting	....	......
	Hastelloy A	Ni 58.0, Mo 20.0, Mn 2.0, Fe 20.0	✓	✓	✓	...	✓	...	...	...	✓	...	...	...	Chemical equipment, pumps, tanks, etc	8.8	1300
	Hastelloy C	Ni 58.0, Mo 17.0, W 5.0, Cr 14.0, Fe 6.0	✓	...	...	...	...	...	...	...	✓	...	...	...	...	....	......
	Hastelloy D	Ni 85.0, Si 10.0, Al 2.0, Cu 3.0	✓	...	...	...	...	...	...	...	✓	...	...	...	Pumps, valves and other cast equipment	7.8	1160
Burgess-Parr Co.	Illium "G"	Ni 60.0, Cr 25.0, Cu 8.0	✓	...	...	...	...	...	...	...	✓	✓	✓	...	Chemical pumps, nozzles, for severe corrosion conditions	8.3	1300
Curtis Bay Copper and Iron Works	Everbrite No. 82	C 0.20, Mn 0.50, Cu 62.00, Ni 30.50, Fe 7.00	✓	...	...	...	...	...	...	...	...	...	✓	...	Steam applications	8.80	1425
	Everbrite No. 92	C 0.35, Mn 2.50, Cu 56.75, Ni 35.50, Fe 1.00, Cr. 3.75	...	✓	✓	✓	✓	...	..	✓	✓	✓	...	...	...	8.80	1595 to 15
International Nickel Co.	Monel Metal	Ni 69.0, Cu 28.0, Fe + Mn + C + Si balance	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Laundry, textile, pickling equipment; valves, fittings, pump rods, tank linings, filter cloth; general chemical resistant; electric hardware; food preparation and service equipment; hospital, ice cream equipment, traffic markers; sewage disposal screens; marine fittings, etc., ornamental apparatus	8.80	1350 to 13
	Nickel	Ni 99.2	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	Caustic evaporators, filter cloth, dairy canning, food preparing equipment, kitchen utensils, chemical and powder making equipment, glass making equipment, pyrometer wire, turbine blading; furnace linings; radio tubes; laboratory apparatus	8.85	1445 to 14
Westinghouse Electric & Manufacturing Co.	Konel	Ni 72.0, Fe 6.5, Co 18.0, Ti 2.5, Al 0.50	✓	✓	✓	✓	...	...	...	✓	✓	✓	...	✓	Vacuum tube filaments and other parts of high vacuum apparatus	8.56	1450
Aluminum Co. of America	No. 43 Alloy	Si 5.0, Al balance	✓	...	...	...	...	...	...	...	✓	...	...	...	...	2.65	625 to 57
	2 S	Al 99.0	...	...	✓	✓	✓	✓	✓	✓	✓	...	...	✓	...	2.71	655 to 63
	3 S	Al 98.0, Mn 1.25	...	...	✓	✓	✓	✓	✓	✓	✓	...	...	...	...	2.73	655 to 63
	Alclad 17ST	17S core, Al surface	...	...	...	...	✓	...	...	...	✓	...	...	...	Aircraft	2.78	643 to 51

[a] Annealed.

[b] Maximum.

[c] Approximate.

[d] Properties within this range depend on section and amount of cold working.

PART IV*a*. COMPOSITIONS AND PHYSICAL AND MECHANICA

Physical Properties									Mechanical Properties at Room Temperature													
Melting Range (Liquidus and Solidus Temperatures), deg. Cent.	Coefficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Form for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.
	Mean 0 to 100° C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.		
1320	(20 to 100° C.) 0.00011	(20 to 500° C.) 0.000081 (20 to 1000° C.) 0.000043	....	....	....	......	108.0	....	Wire	110 000	60 000	......	25.0	55.0	......	183	10.0	29.0	....	....	....	......
1350	(20 to 100° C.) 0.00017	(20 to 500° C.) 0.00015 (20 to 1000° C.) 0.00011	....	....	....	......	112.0	....	Wire	100 000	60 000	......	25.0	50.0	......	183	10.0	29.0	....	....	....	......
1260	(20 to 124° C.) 0.0000121	(20 to 532° C.) 0.0000141 (20 to 998° C.) 0.0000161	0.033	....	....	(20 to 1000° C.) 0.136	108.0	....	Castings	60 000 to 65 000	40 000	......	3.0	2.0	......	156 to 187	9.0	29.0	....	....	211 000	......
1480	....	....	....	....	....	......	....	....	Castings	60 000	......	......	3.5	2.0	......	168	5.0	25.0	....	....	....	......
....	(20 to 100° C.) 0.0000171	....	....	....	....	......	91.3	....	Wire	80 000	40 000	......	40.0	70.0	......	....	....	....	....	....	....	......
....	(20 to 126° C.) 0.0000029	(20 to 506° C.) 0.0000109 (20 to 971° C.) 0.0000146	....	....	....	......	66.4	....	Wire[a]	72 500	24 000	......	39.2	67.5	20 800 000	....	....	....	....	....	....	......
1450	(20 to 125° C.) 0.0000126	(20 to 512° C.) 0.0000150 (20 to 890° C.) 0.000018	....	....	....	......	9.6	....	Wire[a]	65 000 to 75 000	25 000 to 35 000	......	50.0 to 35.0	70.0	......	118 to 135	"B" 65.0	15.0 to 17.0	....	....	....	......
....	(20 to 132° C.) 0.0000149	(20 to 500° C.) 0.0000163 (20 to 960° C.) 0.0000188	....	....	....	......	48.8	(600° C.) 51.5	Wire	63 000	40 000	......	40.0	75.0	......	....	"B" 60.0	....	....	....	....	......
....	....	....	....	....	....	......	48.0	....	....	......	......	......	....	....	......	....	....	....	....	....	....	......
1250	....	(40 to 1095° C.) 0.0000155	....	....	0.096	......	105.0	....	Castings	40 000	......	......	0.5[b]	....	......	512	54.0	72.0	....	....	256 000	......
1260	....	(40 to 1095° C.) 0.0000158	....	....	0.1008	......	90.0	....	Castings Forgings	86 000 134 000	......	......	0.5[b]	....	......	402	45.0	53.0	....	....	259 000	......
1260	....	(40 to 1095° C.) 0.0000158	....	....	0.1008	......	91.0	....	Castings	66 000	......	......	....	....	......	444	48.0	58.0	....	....	193 000	......
....	....	....	....	....	....	......	....	....	Weld metal	40 000	......	......	....	....	......	250 to 500	....	....	....	....	177 000	......
1300	....	(200 to 600° C.) 0.0000107	0.004	....	....	......	126.7	....	Forgings[a]	100 000 to 140 000	50 000 to 70 000	......	40.0 to 30.0	40.0 to 30.0	......	207	"B" 97.0	....	....	....	....	......
....	....	(200 to 600° C.) 0.0000142	....	....	....	......	....	....	Castings	50 000 to 60 000	......	......	....	....	......	207	....	....	....	....	....	......
1160	....	(200 to 600° C.) 0.0000116	0.005	....	....	......	113.0	....	Castings	......	......	......	....	....	......	364	....	....	....	....	....	......
1300	0.0000135	....	....	....	0.112	......	121.9	....	Castings	73 000	63 800	......	....	14.9	......	137	"B" 82.0	....	....	....	....	......
1425	....	....	....	....	....	......	....	....	Castings	75 000	50 000	......	14.0	....	......	170 to 200	"B" 82.0 to 90.0	26 to 30	....	...	....	......
1595 to 1540	....	....	....	....	....	......	....	....	....	95 000	60 000	......	20.0	....	......	....	....	....	....	....	....	......
1350 to 1300	0.000014	(25 to 300° C.) 0.000015	0.06	....	....	(20 to 400° C.) 0.127	44.5	(0° C.) 42.5	Castings	65 000 to 80 000	30 000 to 40 000	......	35.0 to 25.0	35.0 to 30.0	......	90 to 110	....	14 to 16	....	....	....	......
									Hot rolled bars and forgings	80 000 to 95 000	35 000 to 50 000	25 000 to 40 000	45 0 to 35.0	65.0 to 50.0	26 000 000	125 to 150	....	15 to 17	....	....	....	......
									Cold drawn bars	65 000 to 110 000	25 000 to 80 000	20 000 to 65 000	50.0 to 20.0	75.0 to 35.0	26 000 000	80 to 240	....	15 to 45	150	110+	....	......
									Wire[g]	110 000 to 140 000	95 000 to 125 000	......	8.0 to 3.0	45.0 to 35.0	26 000 000	....	....	40 to 50	....	....	....	......
1445 to 1435	....	(25 to 300° C.) 0.000014	0.14	....	....	(20 to 300° C.) 0.112	....	(0° C.) 10.9	Castings	60 000 to 70 000	20 000 to 30 000	......	35 0 to 15 0	50.0 to 30.0	......	75 to 95	....	....	....	....	....	......
									Hot rolled bars and forgings	70 000 to 80 000	30 000 to 40 000	20 000 to 30 000	50 0 to 40.0	65.0 to 55.0	30 000 000	105 to 125	....	15 to 19	100+	95 to 100	....	......
									Cold drawn bars[m]	65 000 to 95 000	20 000 to 80 000	17 000 to 50 000	53 0 to 25 0	75.0 to 40.0	30 000 000	85 to 240	....	11 to 45	....	....	....	......
									Tubes	100 000 to 105 000	85 000 to 95 000	......	20.0 to 15.0	....	......	....	....	30 to 35	....	....	....	......
1450	0.0000107	(0 to 700° C.) 0.0000143	0.054[c]	....	....	......	40.0	(0° C.) 35.0 (400° C.) 69.0 (800° C.) 100.0 (1000°C.) 108.0	Forgings	100 000	40 000	30 000	35.0	55.0	29 400 000	140	....	....	....	....	....	......
625 to 577	0.0000213	....	0.42	....	0.23	......	4.3	....	Castings	19 000	9 000	......	4.0	....	10 000 000	40	"E" 39.0	12.0[p]	....	....	25 000	9 000
655 to 637	0.0000234	....	0.50	....	0.23	......	2.95	....	•	13 000 to 24 000	4 000 to 21 000	......	40.0 to 10.0	....	10 000 000	21 to 38	"E" 22.0 to 43.0	7.0 to 15.0[p]	....	....	13 000[o]	4 000[o]
655 to 637	0.0000234	....	0.45	....	0.23	......	4.3	....	•	16 000 to 29 000	5 000 to 25 500	......	40.0 to 10.0	....	10 000 000	28 to 55	"B" 51 to 68	1.0 to 23[p]	....	....	16 000[o]	5 000[o]
643 to 516	0.0000213	....	....	....	0.23	......	....	....	Plates and sheets	53 000	33 000	......	20.0	....	10 000 000	....	....	....	....	....	53 000	33 000

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working.

[g] Hardened.

[k] Simple and small shapes.

[l] Shear properties for as drawn and normalized only.

[m] Shear properties for cold wo

COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																		Mechanical Properties at Elevated Temperatures					
					Hardness Number			Impact Strength															
Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.	Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination	
60 000	......	25.0	55.0	......	183	10.0	29.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Rea
60 000	......	25.0	50.0	......	183	10.0	29.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Rea
40 000	......	3.0	2.0	......	156 to 187	9.0	29.0	....	....	211 000	......	35 000	....	......	....	......	....	....	....	....	....	....	Rea
......	......	3.5	2.0	......	168	5.0	25.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Rea
40 000	......	40.0	70.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Rea
24 000	......	39.2	67.5	20 800 000	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	..
25 000 to 35 000	......	50.0 to 35.0	70.0	......	118 to 135	"B" 65.0	15.0 to 17.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	..
40 000	......	40.0	75.0	......	....	"B" 60.0	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Rea
......	......	....	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	..
......	......	0.5^b	....	......	512	54.0	72.0	....	....	256 000	......	....	....	......	....	......	....	....	....	....	....	....	Unm
......	......	0.5^b	....	......	402	45.0	53.0	....	....	259 000	......	....	....	......	....	......	....	....	....	....	....	....	Unm
......	......	....	....	......	444	48.0	58.0	....	....	193 000	......	....	....	......	....	......	....	....	....	....	....	....	Unm
......	......	....	....	......	250 to 500	....	....	....	....	177 000	......	....	....	......	....	......	....	....	....	....	....	....	Unm
60 000 to 70 000	......	40.0 to 30.0	40.0 to 30.0	......	207	"B" 97.0	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Mac
......	......	....	....	......	207	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Mac slo
......	......	....	....	......	364	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	With ca
63 800	......	....	14.9	......	137	"B" 82.0	....	....	....	....	......	....	23 900	......	....	......	....	....	....	....	....	....	Like
50 000	......	14.0	....	......	170 to 200	"B" 82.0 to 90.0	26 to 30	....	...	....	......	....	....	......	....	......	....	....	....	....	....	....	Mac
60 000	......	20.0	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Toug
30 000 to 40 000	......	35.0 to 25.0	35.0 to 30.0	......	90 to 110	....	14 to 16	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Satis
35 000 to 50 000	25 000 to 40 000	45 0 to 35.0	65.0 to 50.0	26 000 000	125 to 150	....	15 to 17	....	....	....	......	....	....	......	....	......	35 000	....	....	....			
25 000 to 80 000	20 000 to 65 000	50 0 to 20.0	75.0 to 35.0	26 000 000	80 to 240	....	15 to 45	150	110+	....	......	....	80 000^l	50 000	320	8 000 000 to 9 000 000	35 000 to 50 000	....	....	....			
95 000 to 125 000	......	8.0 to 3.0	45.0 to 35.0	26 000 000	....	....	40 to 50	....	....	....	......	....	....	......	....	9 000 000	....	....	....	....			
20 000 to 30 000	......	35 0 to 15 0	50.0 to 30.0	......	75 to 95	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Satis
30 000 to 40 000	20 000 to 30 000	50 0 to 40.0	65.0 to 55 0	30 000 000	105 to 125	....	15 to 19	100+	95 to 100	....	......	....	....	......	....	......	....	....	....	....			
20 000 to 80 000	17 000 to 50 000	53 0 to 25 0	75.0 to 40.0	30 000 000	85 to 240	....	11 to 45	....	....	....	......	....	60 000 to 70 000^r	10 000 to 12 000	....	10 000 000	....	....	....	....			
85 000 to 95 000	......	20.0 to 15.0	....	......	....	....	30 to 35	....	....	....	......	....	....	......	....	......	....	....	....	....			
40 000	30 000	35.0	55.0	29 400 000	140	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Read
9 000	......	4.0	....	10 000 000	40	"E" 39.0	12.0^p	....	....	25 000	9 000	....	....	......	....	......	6 500	....	....	....	....	....	Use t sha for har
4 000 to 21 000	......	40.0 to 10.0	....	10 000 000	21 to 38	"E" 22.0 to 43.0	7.0 to 15.0^p	....	....	13 000^o	4 000^o	....	....	......	....	......	5 000 to 8 500	....	....	....	....	....	Use t sha for har
5 000 to 25 500	......	40.0 to 10.0	....	10 000 000	28 to 55	"B" 51 to 68	1.0 to 23^p	....	....	16 000^o	5 000^o	....	....	......	....	......	7 000 to 10 500	....	....	....	....	....	Use t sha for har
33 000	......	20.0	....	10 000 000	....	....	....	....	....	53 000	33 000	....	....	......	....	......	....	....	....	....	....	....	....

[l] Shear properties for as drawn and normalized only.

[m] Shear properties for cold worked and annealed only.

[o] Soft.

[p] Magnifier hammer.

PLATE XI.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART IV*a*.

Fabricating Properties														Trade Name of Alloy	Manufacturer
Machining	Hot Working		Cold Working	Welding					Brazing	Soldering	Precautions to be Observed				
	Optimum Temperature Range, deg. Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance			In Design	In Fabricating	In Use		
Readily machineable	1150	....	......	..	✓	✓	✓	✓	..	✓	Keep sodium silicate from heating elements	....	....	Nichrome IV (Karma)...	Driver-Harris Co.
Readily machineable	1175 to 1205	....	......	..	✓	✓	✓	✓	..	✓	....	....	....	Nichrome..............	
Readily machineable	1000	....	......	..	✓	✓	✓	..	..	..	....	....	....	Nichrome..............	
Readily machineable	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Chromax..............	
Readily machineable	....	....	......	..	✓	✓	✓	✓	..	✓	....	....	....	No. 193 Alloy..........	
....	1120 to 1150	....	......	✓	✓	✓	✓	✓	✓	✓	....	....	Loses its low coefficient of expansion above 150° C.	Invar..................	
....	480 to 650	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Grade "A" Nickel......	
Readily machineable	1040	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Advance (Ideal)........	
....	870	....	......	..	..	..	..	..	..	✓	Low thermal E.M.F. to copper	....	Artifically age to avoid change of resistance with time	Manganin..............	
Unmachineable	....	....	......	..	✓	✓	✓	✓	✓	..	For welding procedure refer to manufacturer	....	....	Haynes Stellite No. 1....	Haynes Stellite Co.
Unmachineable	1065	....	......	..	✓	✓	✓	✓	✓	..	....	....	....	Haynes Stellite No. 6....	
Unmachineable	....	....	......	..	✓	✓	✓	✓	✓	..	....	....	....	Haynes Stellite No. 12...	
Unmachineable	....	....	......	..	✓	✓	✓	..	..	..	....	....	....	Hascrome..............	
Machines well	1000 to 1200	....	......	..	✓	..	✓	..	..	..	....	Follow cold work by annealing	....	Hastelloy A............	
Machineable with slow speeds	....	....	......	..	✓	..	✓	..	..	..	....	....	....	Hastelloy C............	
With tungsten carbide tools	....	....	......	..	..	..	..	..	..	..	....	....	....	Hastelloy D............	
Like cast steel	....	....	......	✓	✓	✓	✓	..	✓	✓	....	....	....	Illium "G"............	Burgess-Parr Co.
Machines like bronze	....	....	......	..	..	..	..	..	..	..	....	....	....	Everbrite No. 82........	Curtis Bay Copper and Iron Works
Tough	1040	....	......	✓	✓	✓	✓	..	..	..	....	....	....	Everbrite No. 92........	
Satisfactory	980 to 1150	Avoid heavy reduction between 650 and 980° C.	25 to 50	..	✓	✓	✓	✓	✓	✓	....	....	....	Monel Metal...........	International Nickel Co.
Satisfactory	980 to 1230	....	25 to 50	..	✓	✓	✓	✓	✓	✓	....	....	....	Nickel.................	
Readily machineable	1000 to 1150	Hot, short above 1250° C.	50 to 75	..	✓	..	✓	✓	✓	✓	Alternate prolonged cycles of oxidation and reduction may produce extreme embrittlement when maximum of temperature cycle ranges between 900 and 1000° C.	....	Do not use continuously under oxidizing conditions at temperatures above 700° C.	Konel..................	Westinghouse Electric & Manufacturing Co.
Use tools similar in shape as those used for wood but of harder temper	....	....	......	..	✓	✓	✓	✓	..	✓	....	....	....	No. 43 Alloy...........	Aluminum Co. of America
Use tools similar in shape as those used for wood but of harder temper	315 to 485	....	75.0	..	✓	✓	✓	✓	..	✓	....	....	....	2 S....................	
Use tools similar in shape as those used for wood but of harder temper	425 to 485	....	75.0	..	✓	✓	✓	✓	..	✓	....	....	....	3 S....................	
....	425 to 460	....	......	..	✓	✓	✓	✓	..	✓	....	....	....	Alclad 17ST............	

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[r] Shear Properties for cold worked and annealed only.

PLATE XII.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND
HEAT-RESISTANT ALLOYS.

PART IV*b*

Corrosion-Resistant Properties

Driver-Harris Co.
Haynes Stellite Co.
Burgess-Parr Co.
International Nickel Co.
Westinghouse Electric & Manufacturing Co.
Aluminum Co. of America

R = Recommended. N = Not recommended. V = Varies with individual conditions; consult manufacturer

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																			
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydro-carbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen	
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.
Driver-Harris Co.	Nichrome IV (Karma)	1150	....	1150	....	1150	....	....	....	....	....	1150	....	....	....	....	....	....	....	1150	....
	Nichrome	995	....	995	....	995	....	995	....	995	....	....	....	....	....	....	....	....	....	995	....
	Nichrome	1000	....	1050	....	1050	....	1050	....	1050	....	1050	....	....	....	....	....	....	....	....	....
	Chromax	900	....	900	....	900	....	900	....	900	....	900	....	....	....	....	....	....	....	....	....
	No. 193 Alloy	315	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Grade "A" Nickel	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Advance (Ideal)	1000	....	1000	....	1000	....	1000	....	1000	....	1000	....	....	....	....	....	....	....	1000	....
Haynes Stellite Co.	Haynes Stellite No. 1	1000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Haynes Stellite No. 6	1000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Haynes Stellite No 12	1000	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Hastelloy A	800	....	800	....	800	....	800	....	800	....	800	....	....	....	....	....	....	....	....	....
	Hastelloy C	1000	....	1000	....	1000	....	1000	....	1000	....	1000	....	....	....	....	....	....	....	....	....
	Hastelloy D	800	....	800	....	800	....	800	....	800	....	800	....	....	....	....	....	....	....	....	....
Burgess-Parr Co.	Illium "G"	980	....	980	....	980	....	980	....	980	....	....	....	....	....	....	..	....	....	....	....
International Nickel Co.	Monel Metal	480 to 540	....	480 to 540	[h]	1350	[h]	....	....	900 to 1000	....	....	....	....	....	....	....	....	....	....	....
	Nickel	650 to 760	....	650 to 760	[h]	1445	[h]	....	....	650 to 760	....	....	....	....	....	....	....	....	....	850	....
Westinghouse Electric & Manufacturing Co.	Konel	700	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Aluminum Co. of America	No. 43 Alloy	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	2-S	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	3-S	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Alclad 17ST	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

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[a] Above room temperature.

[h] In absence of sulfur fumes.

turer.

PART IV*b*. CORROSION-RESIST

es of ogen	Chlorine		Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia		Fused Caustic Alkalis		Fused Chlorides		Form of Material	Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines		
Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.		Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution
....	....	....	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..
....	....	....	....	....	995	....	995	*h*	995	*h*	....	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R
....	....	....	....	....	1050	....	1050	*h*	1050	*h*	....	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R
....	....	....	....	....	900	....	900	....	900	....	....	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R V	R V	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R	R R	20 *c*	R R	R R
....	....	....	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..
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....	....	....	....	....	1000	....	1000	....	1000	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..
....	....	....	....	....	....	....	....	....	....	....	....	20 20 20 20 70	N N N R R	N N N R R	N N N R R	20 20 20 20 70 Boiling	R R R	R R R N N N	R R R	20 20 20 20 70 Boiling	N N N R R R	N N N R R R	N N N R R R	20 20 20 20 70	R R R R R	R R R R R	R R R R R	20 20 20 20 70	R R R R R	R R R R R	R R R R R	20 20 20 20 70	R R R R R	R R R R R	R R R R R	20 20 20 20 70	R R R R R	R R R R R
....	....	....	....	....	....	....	....	....	....	....	....	20 70	R R	R R	R R	20 70	R R	R R	R R	20 70	R R	R R	R R	20 70	R R	R R	R R	20 70	R R	R R	R R	20 70	R R	R R	R R	20 70	R R	R R
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....	....	....	....	....	....	....	....	....	....	....	Cast	20	R	R	R	20	R	R	R	20	R	R	N	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R
												c	R	R	V	*c*	R	R	V	*c*	V	V	N	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R
....	....	....	....	....	....	....	500 to 600	....	....	....	Cast and wrought	...	V	V	V	...	N	N	N	...	V	V	V	...	V	V	V	...	R	R	R	...	R	R	R	...	R	R
....	....	....	....	....	....	....	500 to 600	....	....	....	Cast and wrought	...	V	V	V	...	N	N	N	...	V	V	V	...	R	R	R	...	R	R	R	...	V	V	V	...	R	R
....	....	....	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..
....	....	....	....	....	....	....	....	....	....	....	....	20 *c*	V N	V N	N N	20 *c*	N N	N N	R N	20 *c*	N N	N N	N N	20 *c*	V V	R V	R V	20 *c*	N N	N N	N N	20 *c*	V V	V V	V V	20 *c*	V N	V N
....	....	....	....	....	....	....	....	....	....	....	....	20 *c*	V N	V N	N N	20 *c*	N N	N N	R N	20 *c*	N N	N N	N N	20 *c*	V V	R V	R V	20 *c*	N N	N N	N N	20 *c*	V V	V V	V V	20 *c*	V N	V N
....	....	....	....	....	....	....	....	....	....	....	....	20 *c*	V N	V N	N N	20 *c*	N N	N N	R N	20 *c*	N N	N N	N N	20 *c*	V V	R V	R V	20 ...	N ..	N ..	N ..	20 *c*	V V	V V	V V	20 *c*	V N	V N
....	....	....	....	....	....	....	....	....	....	....	....	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	20	V	V

PART IV*b*. CORROSION-RESISTANT PROPERTIES.

Corrosion in Media at Moderate Te

Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
..	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	....	...	....	20	V	20	R	20	R	20	R
	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	....	...	....	*c*	V	...	....	*c*	R	*c*	R
	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	....	...	....	20	V	20	R	20	R	20	R
	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	....	...	....	*c*	V	...	....	*c*	R	*c*	R
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	....	...	....	20	V	20	R	20	R	20	R
	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	...	....	...	....	*c*	V	...	....	*c*	R	*c*	R
	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
0	..	..	R	20	R	R	R	20	R	..	..	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	...	....	...	....
.	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	N	20	R	20	R	20	R
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	N	20	R	20	R	20	R
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	N	20	R	20	R	20	R
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	....	...	....	20	N	20	R	20	R	20	R
0	R	R	R	70	R	R	R	70	R	R	R	70	R	R	R	70	R	R	R												
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	...	....	20	R	20	R	20	R	20	R	20	R
0	R	R	R	70	R	R	R	70	R	R	R	70	R	R	R	70	R	R	R	...	....	70	R	70	R	70	R	70	R	70	R
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	..	...	..	..	..	...	....	20	R	20	N	20	R	20	R	20	R
0	R	R	R	70	R	R	R	70	R	R	R	70	R	R	..	...	..	..	..	...	....	70	R	...	....	70	R	70	R		
0	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	R	20	R	20	N	20	R	20	R	20	R
	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	R	R	R	*c*	V	*c*	V	*c*	N	*c*	R	*c*	R	*c*	R
	V	V	V	...	R	R	R	...	R	R	R	...	R	R	R	...	R	R	R	...	V	...	V	...	V	...	V	...	V	...	V
.	R	R	R	...	R	R	R	...	V	V	V	...	R	R	R	...	R	R	R	...	V	...	V	...	V	...	V	...	R	...	R
.	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....
20	V	R	R	20	N	N	N	20	V	V	V	20	V	V	V	20	V	V	V	20	N	20	N	20	N	20	N	20	R	20	R
	V	V	V	*c*	N	N	N	*c*	V	V	V	*c*	N	N	N	*c*	N	N	N	*c*	N	*c*	N	*c*	N	*c*	N	*c*	V	*c*	R
20	V	R	R	20	N	N	N	20	V	V	V	20	V	V	V	20	V	V	V	20	N	20	N	20	N	20	N	20	R	20	R
	V	V	V	*c*	N	N	N	*c*	V	V	V	*c*	N	N	N	*c*	N	N	N	*c*	N	*c*	N	*c*	N	*c*	N	*c*	V	*c*	R
20	V	R	R	20	N	N	N	20	V	V	V	20	V	V	V	20	V	V	V	20	N	20	N	20	N	20	N	20	R	20	R
	V	V	V	...	..	..	..	*c*	V	V	V	*c*	N	N	N	*c*	N	N	N	*c*	N	*c*	N	*c*	N	*c*	N	*c*	V	*c*	R
..	..	..	..	...	..	..	..	...	..	..	..	20	V	V	V	...	..	..	..	...	....	...	....	...	....	...	....	...	....	...	....

PLATE XII.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART IVb.

rate Temperatures

Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Temperature		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Medium			
...	....	...	....	...	....	...	....	...	....	...	....	....	....	Nichrome IV (Karma)	Driver-Harris Co.
...	....	...	....	20	R	20	R	...	....	...	....	....	....	Nichrome	
...	....	...	....	*c*	R	20	R	20	R	...	N	S-Bearing Gases			
...	....	...	....	20	R						R	Lactic Acid			
...	....	...	....	*c*	R	...	....	.....	....	*c*	R	Molten Sn	....	Nichrome	
											R	Molten Ag			
											N	Na Compounds			
...	....	...	....	20	R	20	R	20	R	...	....	....	....	Chromax	
...	....	...	....	*c*	R										
...	....	...	....	...	....	...	....	...	....	...	....	....	....	No. 193 Alloy	
...	....	...	....	20	R	20	R	...	....	...	....	....	....	Grade "A" Nickel	
...	....	...	....	...	....	...	....	...	....	...	N	Molten Brass	....	Advance (Ideal)	
20	R	20	R	20	R	20	R	...	....	...	....	....	....	Haynes Stellite No. 1	Haynes Stellite Co.
20	R	20	R	20	R	20	R	...	....	...	....	....	....	Haynes Stellite No. 6	
20	R	20	R	20	R	20	R	...	....	...	....	....	....	Haynes Stellite No. 12	
20	R	...	....	20	R	20	R	...	....	...	....	....	....	Hastelloy A	
20	R	...	R	20	R	20	R	20	R	...	....	....	....	Hastelloy C	
...	....	...	....	70	R	70	R	70	R						
20	R	...	....	20	R	20	R	20	R	...	....	....	....	Hastelloy D	
20	V	20	V	20	R	20	R	20	R	20	R	Mixes of HNO_3 + H_2SO_4	Cast	Illium "G"	Burgess-Parr Co.
c	V	*c*	V	*c*	R	*c*	R	...	V	*c*	V	Mixes of HNO_3 + H_2SO_4			
...	V	...	....	...	R	...	R	...	V	...	....	....	Cast and wrought	Monel Metal	International Nickel Co.
...	R	...	....	...	R	...	R	...	N	...	....	....	Cast and wrought	Nickel	
...	....	...	....	...	....	20	R	20	R	...	....	....	....	Konel	Westinghouse Electric & Manufacturing Co.
20	V	20	N	20	R	20	V	20	V	...	....	....	....	No. 43 Alloy	Aluminum Co. of America.
c	V	*c*	N	*c*	R	*c*	V	*c*	V						
20	V	20	N	20	V	20	V	20	V	...	....	....	....	2-S	
c	V	*c*	N	*c*	V	*c*	V	*c*	V						
20	V	20	N	20	V	20	V	20	V	...	....	....	....	3-S	
c	V	*c*	N	*c*	V	*c*	V	*c*	V						
...	....	...	....	20	V	20	V	...	....	...	....	....	....	Alclad 17ST	

PART V*a*

Compositions and Physical and Mechanical Properties

- American Brass Co.
- American Manganese Bronze Co.
- American Metal Products Co.
- Barber Asphalt Co.
- Chase Brass & Copper Co.

Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured: Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Types of Service for Which Recommended: Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical	Typical Applications	Specific Gravity	Melting Range (Liquidus and Solidus Temperatures), deg. Cent.
American Brass Co.	Admiralty	Cu 70.0, Zn 29.0, Sn 1.00	...	...	...	....	✓	...	✓	✓	✓	....	....	....	Condenser tubes	8.54	935 to 895
	Tobin Bronze	Cu 60.0, Zn 39.25, Sn 0.75	...	✓	✓	✓	✓	✓	✓	✓	✓	....	✓	....	Piston rods, propeller shafts, nuts, bolts, welding rod, etc.	8.40	885
	Grade "C" Phosphor Bronze	Cu 92.0, Sn 8.00	...	...	...	✓	✓	...	✓	✓	✓	....	✓	✓	Switch parts, contact springs, etc., in contact with sea water for paper mill screens, rolls, bearings, and bushings	8.82	1025 to 815
	Grade "D" Phosphor Bronze	Cu 89.5, Sn 10.5	...	...	...	✓	✓	...	✓	✓	✓	....	✓	✓	Switch parts, contact springs, etc., in contact with sea water for paper mill screens, rolls, bearings, and bushings	8.78	1000 to 800
	Grade "A" Phosphor Bronze	Cu 96.0, Sn 3.75, P 0.25	...	...	...	✓	✓	...	✓	✓	✓	....	✓	....	To sea water for paper mill screens, rolls, springs. Does not season crack	8.88	1050 to 905
	Commercial Bronze	Cu 90.0, Zn 10.0	...	✓	✓	✓	✓	✓	✓	✓	✓	....	....	....	Window screen wire, automobile radiators, ornamental purposes	8.80	1050 to 1015
	Red Brass, 85 per cent	Cu 85.0, Zn 15.0	...	✓	✓	✓	✓	✓	✓	✓	✓	....	....	....	Corrosion resistance to atmospheric conditions, plumbing and hardware	8.73	1025 to 985
	Red Brass, 80 per cent	Cu 80.0, Zn 20.0	...	...	...	✓	✓	...	✓	✓	✓	....	....	....	Resistant to atmospheric and salt water corrosion	8.67	1000 to 960
	Deep Drawing Brass 70/30	Cu 70.0, Zn 30.0	...	...	...	✓	✓	...	✓	✓	....	....	....	....	Seamless tubes, cartridges, primers, shot shells, etc.	8.53	960 to 915
	Common High Brass	Cu 65.0, Zn 35.0	...	...	...	✓	✓	...	✓	✓	....	....	....	....	Lamp fixtures, automobile radiators, ornamental purposes, etc.	8.46	930 to 905
	Hard Ware Bronze	Cu 85.0, Zn 13.25, Pb 1.75	...	...	...	✓	....	✓	...	...	✓	....	....	✓	Bolts, screws, nuts, tie rods, electrical construction, etc.	8.76	....
	Ambrac "A"	Cu 75.0, Zn 5.0, Ni 20.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	....	....	....	Laundry machinery, pulp and paper machinery	8.84	1150
	Ambrac "B"	Cu 65.0, Zn 5.0, Ni 30.0	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	....	Laundry machinery, pulp and paper machinery	8.86	1220
	18-per-cent Nickel Alloy (Grade "A")	Cu 65.0, Zn 17.0, Ni 18.0	✓	...	...	....	✓	...	✓	✓	✓	....	....	✓	Silver plated ware, pipes for plumbing, resistance wire and strips	8.75	1110
	Tempaloy "A"	Cu 95.0, Ni 4.0, Si 1.0	...	✓	✓	✓	✓	✓	✓	✓	✓		✓	....	....	8.82	1083 to 1044
	Tempaloy "B"	Cu 89.2, Ni 5.0, Al 5.0, Si 0.8	...	✓	✓	✓	✓	✓	✓	✓	✓	....	✓	....	....	....	....
	Everdur	Cu 95.4, Si 3.5, Mn 1.1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	....	....	8.46	1019 to 915
	Aluminum Bronze	Cu 92.0, Al 6.4, balance Fe + Ni + Sn + Mn	...	✓	✓	✓	....	....	...	✓	✓	✓	✓	....	Pump parts, diaphragms, and pickling equipment	8.00	1070 to 1050
	Deoxidized Copper	Cu (+Ag) 99.90, P 0.053	...	✓	✓	✓	✓	✓	✓	✓	✓	....	....	....	Sugar mills, mechanical refrigerators, coolers, condensers, evaporators, etc.	8.93	1083
American Manganese Bronze Co.	Resistac	Cu 89.0, Al 10.0, Fe 1.0	✓	✓	✓	....	✓	✓	✓	..	✓	✓	✓	....	Acid resisting castings and forgings, paper mills, chemical plants, steel mills	8.00	1065
	Hytensl Bronze	Cu 65.0, Zn 35.0	✓	✓	...	✓	✓	✓	✓	...	✓	....	....	....	Pressure work, heavy duty bearings, paper machinery parts, acid resisting castings	7.74	1095 to 1010
American Metal Products Co.	Ampco	Cu 88.0, Al 8.0, Fe 4.0	✓	✓	✓	✓	✓	....	....	...	✓	✓	....	....	....	7.80	1205 to 1035
Barber Asphalt Co.	Barberite	Cu 88.5, Ni 5.0, Sn 5.0, Si 1.5	✓	...	...	....	....	...	...	...	✓	....	....	....	....	8.8	1070
Chase Brass & Copper Co.	Admiralty	Cu 70.0, Zn 29.0, Sn 1.0	...	...	...	✓	✓	..	✓	✓	✓	....	✓	....	Condenser tubes	8.54	935
	Chamet Bronze	Cu 60.0, Zn 39.25, Sn 0.75	...	✓	✓	✓	✓	✓	✓	✓	✓	....	✓	....	Welding rod	8.40	935
	Common High Brass	Cu 65.0, Zn 35.0	...	...	...	✓	✓	✓	✓	✓	✓	....	✓	✓	Contacts, etc., in light sockets, deep drawing, stamping, etc.	8.47	930 to 905
	Cartridge Brass	Cu 70.0, Zn 30.0	...	...	...	✓	✓	✓	✓	✓	✓	....	✓	✓	Contacts, etc., in light sockets, cartridge cases, brazing brass, seep drawing	8.53	955 to 920
	Red Brass	Cu 80.0, Zn 20.0	...	...	...	✓	✓	✓	✓	✓	✓	....	✓	....	Used for reddish color	8.67	1005 to 965
	Red Brass	Cu 85.0, Zn 15.0	...	...	...	✓	✓	✓	✓	✓	✓	....	✓	....	Jewelry, vanity boxes, etc., tubes for salt water, mild acids and water supplies	8.73	1030 to 990
	Commercial Bronze	Cu 90.0, Zn 10.0	...	✓	...	✓	✓	...	✓	✓	✓	....	✓	....	Hardware, red metal parts	8.80	1050 to 1015
	Phosphor Bronze	Cu 95.0, Sn 5.0	...	...	...	✓	✓	✓	✓	✓	✓	....	✓	✓	Springs, chains, switch blades, contacts, etc.	8.94	495
	Deoxidised Copper	Cu 99.9, P 0.01	...	✓	...	✓	✓	✓	✓	✓	✓	....	....	....	Water tubing, gasoline and oil lines, refrigerators, heater and condenser tubes	8.92	1080
	Hardware Bronze	Cu 89.0, Zn 9.0, Pb 2.0	...	...	...	✓	....	✓	...	✓	✓	....	✓	....	Hardware	8.85	1050
	18-per-cent Nickel Alloy	Cu 65.0, Zn 17.0, Ni 18.0	...	...	...	✓	✓	...	...	✓	✓	....	✓	✓	High resistance material, silver plated table ware, white metal parts	8.75	1110

[b] Maximum. [g] Hardened. [m] Elongation in 10 in. [o] Soft.

PART V*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PRO

Physical Properties									Mechanical Properties at Room Temperature															
(Liquidus and Solidus Temperatures), deg. Cent.	Coefficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Forms for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear
	Mean 0 to 100° C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.				
to 895	0.0000185	....	....	....	....	......	....	....	Plates and sheets	45 000 to 95 000	19 000[o]	......	60.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
									Tubes	53 000	19 500	......	71.0	....	......	....	....	....	....	....	....	......	....	
									Wire	57 000 to 125 000	......	......	42.0 to 2.0	....	......	....	....	....	....	....	....	......	....	
885	0.0000198	....	....	....	....	......	6.8	....	Hot rolled bars	54 000	25 000	......	50.0	....	......	59.0	....	....	....	....	....	......	....	
									Cold rolled bars	75 000	65 000	......	25.0	....	......	100.0	"B" 75.0	....	....	....	....	......	....	39
									Plates and sheets	54 000 to 90 000	35 000 to 78 000	......	50.0 to 25.0	....	......	59 to 175	"B" 57.0 to 96.0	26.0 to 68.0[p]	....	....	....	......	....	
to 815	0.0000176	....	....	....	....	......	13.2	....	Plates and sheets	50 000 to 100 000	20 000 to 50 000	......	45.0 to 1.0	....	......	60.0 to 140.0	"B" 30.0 to 90.0	....	....	....	....	......	....	
									Wire	50 000 to 150 000	......	......	38.0 to 0.0	....	......	....	....	....	....	....	....	......	....	
to 800	0.0000176	....	....	....	....	......	16.3	....	Cold rolled bars	92 000	83 000	30 000	29.0	....	......	117 to 218	....	....	....	....	....	......	....	
									Plates and sheets	60 000 to 115 000	25 000 to 85 000	......	60.0 to 5.0	....	......	74.0 to 190	"B" 52.0 to 100.0	....	....	....	....	......	....	
to 905	0.0000173	....	....	....	....	......	12.4	....	Cold rolled bars	45 000 to 90 000	20 000 to 45 000	......	40.0 to 10.0	....	......	....	....	....	....	....	....	......	....	
									Plates and sheets	45 000 to 95 000	20 000 to 50 000	......	40.0 to 15.0	....	......	60 to 180	"B" 30.0 to 70.0	....	....	....	....	......	....	
									Wire	150 000[b]	......	......	10.0 to 0.5	....	......	....	....	....	....	....	....	......	....	
to 1015	0.0000174	....	0.44	....	....	......	4.2	....	Cold rolled bars	32 000 to 44 000	12 000 to 18 000	......	40.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
									Plates and sheets	32 000 to 65 000	......	......	40.0 to 1.0	....	......	50 to 127	"B" 1.0 to 81.0	....	....	....	....	......	....	
									Wire	42 000 to 100 000	......	......	35.0 to 1.0[n]	....	......	....	....	....	....	....	....	......	....	
to 985	0.0000176	....	0.35	....	....	......	4.7	....	Plates and sheets	42 000 to 75 000	18 000 to 50 000	......	43.0 to 4.0	....	......	52 to 135	"B" 10.0 to 88.0	....	....	....	....	......	....	
									Tubes	45 000	20 000	......	55.0	68.0	......	....	....	....	....	....	....	......	....	
									Wire	35 000 to 128 000	......	......	28.0 to 1.0[n]	....	......	....	....	....	....	....	....	......	....	
to 960	0.0000180	....	0.34	....	....	......	5.3	....	Plates and sheets	43 000 to 85 000	......	......	50.0 to 4.0	....	......	53.0 to 150	"B" 11.0 to 92.0	....	....	....	....	......	....	
									Wire	125 000[g]	......	......	2.0	....	......	....	....	....	....	....	....	......	....	
to 915	0.0000185	....	0.29	....	....	......	6.2	....	Plates and sheets	47 000 to 86 000	38 000[g]	......	58.0 to 4.0	....	......	53 to 156	"B" 22.0 to 93.0	....	....	....	....	......	....	
to 905	0.0000189	....	0.36	....	....	......	6.4	....	Cold rolled bars	45 000 to 70 000	......	......	50.0 to 3.0	....	......	....	....	....	....	....	....	......	....	
									Plates and sheets	45 000 to 85 000	36 000[o]	......	58.0 to 4.0	....	......	52 to 153	"B" 30.0 to 85.0	....	....	....	....	......	....	
									Wire	50 000 to 125 000	......	......	50.0 to 2.0	....	......	....	....	....	....	....	....	......	....	
.....	0.0000178	....	....	....	....	......	4.9	....	Cold rolled bars	38 000 to 68 000	23 000 to 58 000	......	54.0 to 15.0	72.0 to 49.0	......	62 to 118	"B" 25.0 to 67.0	....	....	....	....	......	....	
150	0.0000164	....	....	....	....	......	27.7	....	Castings	44 400	14 800	......	19.4	....	19 000 000	....	....	....	....	....	....	......	....	
									Hot rolled bars	50 000	16 000	......	29.0	....	......	75 to 100	"B" 30.0 to 65.0	....	....	....	....	......	....	
									Cold rolled bars	80 000	29 000	......	13.0	55.0	......	100 to 160	"B" 58.0 to 85.0	....	....	....	....	......	....	
									Plates and sheets	50 000 to 83 000	16 000 to 75 000	......	35.0 to 5.0	....	......	70 to 125	"B" 35.0 to 72.0	16.0 to 35.0[p]	....	....	....	......	....	
									Tubes	59 000 to 77 000	54 000	30 000	5.0	....	......	69 to 82	"B" 69.0 to 81.0	34 to 49[p]	....	....	....	......	....	
									Wire	55 000 to 125 000	20 000	10 000	1.0	....	......	....	....	....	....	....	....	......	....	
220	....	....	....	....	....	......	38.5	....	Hot rolled bars	65 000	......	......	30.0	....	......	....	....	....	....	....	....	......	....	
									Cold rolled bars	80 000	......	......	10.0	....	......	....	....	....	....	....	....	......	....	
									Plates and sheets	65 000 to 120 000	......	......	30.0 to 2.0	....	......	90 to 190	"B" 55.0 to 95.0	....	....	....	....	......	....	
									Wire	130 000[g]	......	......	2.0	....	......	....	....	....	....	....	....	......	....	
110	....	....	0.079	....	....	......	30.7	....	Plates and sheets	58 000 to 95 000	......	......	33.0 to 2.0	....	18 000 000	77 to 158	"B" 40.0 to 87.0	....	....	....	....	......	....	
o 1044	....	....	....	....	....	......	....	....	Hot rolled bars	45 000	......	......	25.0	....	......	60.0	"B" 40.0	....	....	....	....	......	....	
									Cold rolled bars[g]	120 000	105 000	......	12.0	....	......	110.0	"B" 96.0	....	....	....	....	......	....	
.....	....	....	....	....	....	......	....	....	Cold rolled bars	160 000	117 000	......	0.5	....	......	275	....	....	....	....	....	......	....	
o 915	0.0000169	....	0.078	....	....	......	27.7	....	Castings	55 800	30 000	......	22.3	22.6	15 000 000	103	....	....	....	....	....	......	....	
									Forgings	65 000	31 000	......	57.0	55.0	15 000 000	96	....	....	....	....	....	......	....	
									Hot rolled bars	55 000	15 000	......	87.0	75.0	15 000 000	60	....	....	....	....	....	......	....	
									Cold rolled bars	71 000 to 100 000	56 000 to 83 000	......	42.0 to 15.0	68.0 to 44.0	15 000 000	141 to 189	....	....	....	....	....	......	....	
									Plates and sheets	50 000 to 93 000	20 000 to 87 000	......	21.0 to 8.0	69.0 to 33.0	15 000 000	59 to 170	"B" 77.0 to 99.0	....	....	....	....	......	....	
									Tubes	52 000 to 87 000	......	......	92.0 to 26.0	66.0 to 45.0	15 000 000	59 to 170	....	....	....	....	....	......	....	
									Wire	58 000 to 148 000	......	......	1.0 to 49.0	....	15 000 000	....	....	....	....	....	....	......	....	
1050	0.0000165	....	....	....	....	......	13.6	....	Hot rolled bars	72 000 to 80 000	35 000 to 40 000	......	30.0 to 20.0	....	......	60 to 150	"B" 20.0 to 100.0	....	....	....	....	......	....	
									Plates and sheets	50 000 to 60 000	20 000 to 24 000	......	30.0 to 25.0	....	......	60 to 170	"B" 20.0 to 100.0	....	....	....	....	......	....	
									....	75 000	30 000	......	20.0	....	......	....	....	....	....	....	....	......	....	
83	0.0000169	....	....	....	....	......	2.4	....	Castings	33 000	......	......	....	....	......	....	....	....	....	....	....	......	....	
									Forgings	33 000	......	......	....	....	......	....	....	....	....	....	....	......	....	
									Cold rolled bars	47 800	......	......	19.3	....	......	95	....	....	....	....	....	......	....	
									Plates and sheets	35 000 to 55 000	16 000 to 44 000	......	35.0 to 5.0	70.0 to 60.0	......	....	"B" 0 to 65.0	....	....	....	....	......	....	
									Tubes	45 000 to 60 000	......	......	10.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
									Wire	35 000 to 60 000	......	......	28.7[n]	....	......	....	....	....	....	....	....	......	....	
65	0.00000169	....	0.016	....	....	......	....	....	Castings	75 000	37 000	......	20.0	15.0	......	135	....	....	....	....	....	30 000	....	
									Forgings	100 000	60 000	......	6.0	6.0	......	185	....	....	....	....	....	39 000	....	
									Hot rolled bars	100 000	60 000	......	6.0	6.0	......	....	....	....	....	....	....	39 000	....	
									Plates and sheets	100 000	60 000	......	6.0	6.0	......	....	....	....	....	....	....	39 000	....	
1010	0.0000180	....	0.023	....	....	......	....	....	Castings	115 000	70 000	......	10.0 to 12.0	10.0 to 12.0	15 000 000	240	....	....	....	....	....	60 000	....	
									Forgings	120 000	73 000	......	8.0 to 10.0	8.0 to 10.0	15 000 000	240	....	....	....	....	....	65 000	....	
									Hot rolled bars	120 000	73 000	......	8.0 to 10.0	8.0 to 10.0	15 000 000	240	....	....	....	....	....	65 000	....	
									Plates and sheets	120 000	73 000	......	8.0 to 10.0	8.0 to 10.0	15 000 000	240	....	....	....	....	....	65 000	....	
1035	....	....	....	....	....	......	....	....	Castings	75 000 to 100 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
									Forgings	90 000 to 116 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
									Hot rolled bars	100 000 to 140 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
									Cold rolled bars	100 000 to 140 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
									Plates and sheets	100 000 to 140 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
									Shapes	100 000 to 140 000	......	......	20.0 to 4.0	18.0 to 6.0	......	149 to 340	....	24.0 to 60.0	....	....	....	......	....	
0	....	....	....	....	....	......	....	....	Castings	56 800	41 500	......	6.6	6.1	......	77.0	....	....	....	....	....	41 500	....	
5	0.0000203	....	....	....	....	......	....	....	Tubes	50 000 to 95 000	......	......	60.0 to 5.0	....	......	....	60.0 to 110.0[q]	....	....	....	....	......	....	
5	0.0000198	....	....	....	....	......	....	....	Hot rolled bars	55 000	25 000	......	50.0	....	......	....	....	....	....	....	....	......	....	
									Cold rolled bars	75 000	65 000	......	25.0	....	......	....	....	....	....	....	75 000	65 000	....	
									Tubes	55 000 to 80 000	......	......	16.0	....	......	....	....	....	....	....	....	......	....	
									Wire	130 000	......	......	....	....	......	....	....	....	....	....	....	......	....	
905	0.0000203	....	....	....	....	......	....	....	Cold rolled bars	47 000 to 75 000	......	......	....	....	......	....	45.0 to 100.0[q]	....	....	....	....	......	....	
									Plates and sheets	47 000 to 90 000	20 000 to 65 000	......	60.0 to 5.0	....	......	....	45.0 to 110.0[q]	7.5 to 40.0	....	....	....	......	....	
									Wire	47 000 to 130 000	......	......	60.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
920	0.0000202	....	....	....	....	......	6.2	....	Cold rolled bars	47 000 to 75 000	......	......	....	....	......	....	45.0 to 100.0[q]	....	....	....	....	......	....	
									Plates and sheets	47 000 to 90 000	20 000 to 65 000	......	60.0 to 5.0	....	......	....	45.0 to 110.0[q]	7.5 to 40.0	....	....	....	......	....	
965	0.0000191	....	....	....	....	......	5.3	....	Plates and sheets	43 000 to 85 000	18 000 to 60 000	......	55.0 to 5.0	....	......	....	42.0 to 108.0	....	....	....	....	......	....	
									Tubes	43 000 to 85 000	......	......	55.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
990	0.0000187	....	....	....	....	......	4.7	....	Plates and sheets	42 000 to 75 000	18 000 to 50 000	......	50.0 to 5.0	....	......	....	40.0 to 107.0[q]	....	....	....	....	......	....	
									Tubes	42 000 to 75 000	......	......	50.0 to 5.0	....	......	....	....	....	....	....	....	......	....	
									Wire	42 000 to 120 000	......	......	40.0	....	......	....	....	....	....	....	....	......	....	
015	0.0000182	....	....	....	....	......	4.2	....	Plates and sheets	37 000 to 75 000	......	......	47.0 to 5.0	....	......	....	35.0 to 105.0[q]	7.0 to 37.0	....	....	....	......	....	
									Wire	37 000 to 100 000	......	......	....	......	......	....	....	....	....	....	....	......	....	
	0.0000178	....	....	....	....	......	12.4	....	Plates and sheets	45 000 to 100 000	......	......	50.0 to 5.0	....	......	....	75.0 to 112.0[q]	10.0 to 112.0	....	....	....	......	....	
									Wire	45 000 to 135 000	......	......	....	....	......	....	....	....	....	....	....	......	....	
	0.0000177	....	....	....	....	......	14.1	....	Plates and sheets	34 000 to 60 000	......	......	40.0 to 4.0	....	......	....	20.0 to 95.0[q]	....	....	....	....	......	....	
									Tubes	32 000 to 60 000	......	......	35.0 to 5.0	....	15 000 000	....	20.0 to 95.0[q]	....	....	....	....	......	....	
									Wire	32 000 to 60 000	......	......	....	....	......	....	....	....	....	....	....	......	....	
	0.0000182	....	....	....	....	......	....	....	Cold rolled bars	32 000 to 70 000	......	......	40.0 to 15.0	....	......	....	....	....	....	....	....	......	....	
	....	....	....	....	....	......	30.7	....	Plates and sheets	58 000 to 95 000	......	......	35.0 to 2.0	....	......	....	75.0 to 115.0[q]	....	....	....	....	......	....	

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[p] Magnifier hammer.

[q] $\frac{1}{16}$-in. ball 60 kg. "B" scale.

T Va. COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																			Mechanical Properties at Elevated Temperatures				
						Hardness Number			Impact Strength														
Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.	Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination
45 000 to 95 000	19 000[e]		60.0 to 5.0																				
53 000	19 500		71.0																				
57 000 to 125 000			42.0 to 2.0																				
54 000	25 000		50.0			59.0																	
75 000	65 000		25.0			100.0	"B" 75.0							39 000	26 800								
54 000 to 90 000	35 000 to 78 000		50.0 to 25.0			59 to 175	"B" 57.0 to 96.0	26.0 to 68.0[p]															
50 000 to 100 000	20 000 to 50 000		45.0 to 1.0			60.0 to 140.0	"B" 30.0 to 90.0																
50 000 to 150 000			38.0 to 0.0																				
92 000	83 000	30 000	29.0			117 to 218																	
60 000 to 115 000	25 000 to 85 000		60.0 to 5.0			74.0 to 190	"B" 52.0 to 100.0																
45 000 to 90 000	20 000 to 45 000		40.0 to 10.0																				
45 000 to 95 000	20 000 to 50 000		40.0 to 15.0			60 to 180	"B" 30.0 to 70.0																
150 000[b]			10.0 to 0.5																				
32 000 to 44 000	12 000 to 18 000		40.0 to 5.0																				
32 000 to 65 000			40.0 to 1.0			50 to 127	"B" 1.0 to 81.0																
42 000 to 100 000			35.0 to 1.0[n]																				
42 000 to 75 000	18 000 to 50 000		43.0 to 4.0			52 to 135	"B" 10.0 to 88.0																
45 000	20 000		55.0	68.0																			
35 000 to 128 000			28.0 to 1.0[n]																				
43 000 to 85 000			50.0 to 4.0			53.0 to 150	"B" 11.0 to 92.0																
125 000[g]			2.0																				
47 000 to 86 000	38 000[g]		58.0 to 4.0			53 to 156	"B" 22.0 to 93.0																
45 000 to 70 000			50 0 to 3.0																				
45 000 to 85 000	36 000[o]		58.0 to 4.0			52 to 153	"B" 30.0 to 85.0																
50 000 to 125 000			50.0 to 2.0																				
38 000 to 68 000	23 000 to 58 000		54.0 to 15.0	72.0 to 49.0		62 to 118	"B" 25.0 to 67.0																
44 400	14 800		19.4		19 000 000																		
50 000	16 000		29.0			75 to 100	"B" 30.0 to 65.0																
80 000	29 000		13.0	55.0		100 to 160	"B" 58.0 to 85.0																
50 000 to 83 000	16 000 to 75 000		35.0 to 5.0			70 to 125	"B" 35.0 to 72.0	16.0 to 35.0[p]															
59 000 to 77 000	54 000	30 000	5.0			69 to 82	"B" 69.0 to 81.0	34 to 49[p]															
55 000 to 125 000	20 000	10 000	1.0																				
65 000			30.0																				
80 000			10.0																				
65 000 to 120 000			30.0 to 2.0			90 to 190	"B" 55.0 to 95.0																
130 000[g]			2.0																				
58 000 to 95 000			33.0 to 2.0		18 000 000	77 to 158	"B" 40.0 to 87.0																
45 000			25.0			60.0	"B" 40.0																
120 000	105 000		12.0			110.0	"B" 96.0																
160 000	117 000		0.5			275																	
55 800	30 000		22.3	22.6	15 000 000	103																	
65 000	31 000		57.0	55.0	15 000 000	96																	
55 000	15 000		87.0	75.0	15 000 000	60																	
71 000 to 100 000	56 000 to 83 000		42.0 to 15.0	68.0 to 44.0	15 000 000	141 to 189																	
50 000 to 93 000	20 000 to 87 000		21.0 to 8.0	69.0 to 33.0	15 000 000	59 to 170	"B" 77.0 to 99.0																
52 000 to 87 000			92.0 to 26.0	66.0 to 45.0	15 000 000	59 to 170																	
58 000 to 148 000			1.0 to 49.0		15 000 000																		
72 000 to 80 000	35 000 to 40 000		30.0 to 20.0			60 to 150	"B" 20.0 to 100.0																
50 000 to 60 000	20 000 to 24 000		30.0 to 25.0			60 to 170	"B" 20.0 to 100.0																
75 000	30 000		20.0																				
33 000																							
33 000																							
47 800			19.3			95																	
35 000 to 55 000	16 000 to 44 000		35.0 to 5.0	70.0 to 60.0			"B" 0 to 65.0																
45 000 to 60 000			10.0 to 5.0																				
35 000 to 60 000			28.7[n]																				
75 000	37 000		20.0	15.0		135						30 000											
200 000	60 000		6.0	6.0		185						39 000											
100 000	60 000		6.0	6.0								39 000											
100 000	60 000		6.0	6.0								39 000											
115 000	70 000		10.0 to 12.0	10.0 to 12.0	15 000 000	240						60 000											
120 000	73 000		8.0 to 10.0	8.0 to 10.0	15 000 000	240						65 000											
120 000	73 000		8 0 to 10.0	8.0 to 10.0	15 000 000	240						65 000											
120 000	73 000		8.0 to 10.0	8.0 to 10.0	15 000 000	240						65 000											
75 000 to 100 000			20.0 to 4 0	18.0 to 6.0		149 to 340		24.0 to 60.0															
90 000 to 116 000			20.0 to 4.0	18.0 to 6.0		149 to 340		24.0 to 60.0															
100 000 to 140 000			20.0 to 4.0	18.0 to 6.0		149 to 340		24.0 to 60.0															
100 000 to 140 000			20.0 to 4.0	18.0 to 6.0		149 to 340		24.0 to 60.0															
100 000 to 140 000			20.0 to 4.0	18.0 to 6 0		149 to 340		24.0 to 60.0															
100 000 to 140 000			20.0 to 4.0	18.0 to 6.0		149 to 340		24.0 to 60.0															
56 800	41 500		6.6	6.1		77.0						41 500											
50 000 to 95 000			60.0 to 5.0				60.0 to 110.0[q]																
55 000	25 000		50.0																				
75 000	65 000		25.0								75 000	65 000											
55 000 to 80 000			16.0																				
130 000																							
47 000 to 75 000							45.0 to 100.0[q]																
47 000 to 90 000	20 000 to 65 000		60.0 to 5.0				45.0 to 110.0[q]	7.5 to 40.0															
47 000 to 130 000			60.0 to 5.0																				
47 000 to 75 000							45.0 to 100.0[q]																
47 000 to 90 000	20 000 to 65 000		60.0 to 5.0				45.0 to 110.0[q]	7.5 to 40.0															
43 000 to 85 000	18 000 to 60 000		55.0 to 5.0				42.0 to 108.0																
43 000 to 85 000			55.0 to 5.0																				
42 000 to 75 000	18 000 to 50 000		50.0 to 5.0				40.0 to 107.0[q]																
42 000 to 75 000			50.0 to 5.0																				
42 000 to 120 000			40.0																				
37 000 to 75 000			47.0 to 5.0				35.0 to 105.0[q]	7.0 to 37.0															
37 000 to 100 000																							
45 000 to 100 000			50.0 to 5.0				75.0 to 112.0[q]	10.0 to 112.0															
45 000 to 135 000																							
34 000 to 60 000			40.0 to 4.0				20.0 to 95.0[q]																
32 000 to 60 000			35.0 to 5.0		15 000 000		20.0 to 95.0[q]																
32 000 to 60 000																							
32 000 to 70 000			40.0 to 15.0																				
58 000 to 95 000			35.0 to 2.0				75.0 to 115.0[q]																

PLATE XIII.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.
PART V*a*.

hod of tress mination	Fabricating Properties														Trade Name of Alloy	Manufacturer
	Machining	Hot Working		Cold Working	Welding					Brazing	Soldering	Precautions to be Observed				
		Optimum Temperature Range, deg. Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance			In Design	In Fabricating	In Use		
....	Fair	....	....	......	..	..		✓	..	✓	✓	....	....	....	Admiralty..........	American Brass Co.
....	Good	410	....	......	..	..	..	✓	..	✓	✓	....	....	....	Tobin Bronze..........	
....	Difficult	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Grade "C" Phosphor Bronze	
....	Difficult	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Grade "D" Phosphor Bronze	
....	Tough	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Grade "A" Phosphor Bronze	
....	Tough	900	....	......	..	..	..	✓	..	✓	✓	....	....	....	Commercial Bronze......	
....	Fair	900	....	......	..	.	..	✓	.	✓	✓	....	....	....	Rod Brass, 85 per cent...	
....	Fair	....	....	......	..	..	..	✓	..	✓	✓	....	....	....	Red Brass, 80 per cent...	
....	Fair	....	....	......	..	..	..	✓	..	✓	✓	....	....	....	Deep Drawing Brass 70/30	
....	Fair	....	....	......	..	.		✓	..	✓	✓	....	....	....	Common High Brass....	
....	Good	....	....	......	..		..	✓	..	✓	✓	....	....	....	Hard Ware Bronze......	
....	Difficult	1000	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Ambrac "A".........	
....	Difficult	1100	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Ambrac "B".........	
....	Fair	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	18 per cent Nickel Alloy (Grade "A")	
....	Difficult	900	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Tempaloy "A".........	
....	Difficult	900	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Tempaloy "B".........	
....	Easier than steel	900	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Everdur.............	
....	Difficult	900	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Aluminum Bronze......	
......	Tough	700 to 900	....	......	..	✓	✓	✓	..	✓	✓	....	....	....	Deoxidized Copper......	
.....	Like steel	....	....	......	✓	✓	✓	✓	..	✓	✓	Shrinkage $\frac{3}{16}$ in. per foot, even sections	Work hot	....	Resistac...............	American Manganese Bronze Co.
.....	Like mild steel	....	....	......	✓		.	✓	..	.	..	Allow $\frac{3}{16}$ in. per foot shrinkage	Work hot	Keep temperature below 205° C.	Hytensl Bronze.........	
.....	Same as tool steel	760 to 900	....	......	✓	✓	✓	✓	..	✓	✓	....	....	....	Ampco...............	American Metal Products Co.
.....	Readily machined	....	.. ..	......	..	..		..	..	..	..	....	....	....	Barberite...............	Barber Asphalt Co.
.....	Fair	....	....	......	..	..	.	✓	✓	✓	✓	....	....	....	Admiralty...............	Chase Brass & Copper Co.
.....	Good	760	....	......	✓	..	..	✓	..	✓	✓	....	....	....	Chamet Bronze.........	
....	Fair	....	....	......	..	..	..	✓	✓	✓	✓	....	....	....	Common High Brass.....	
....	Fair	....	....	......	..	..	..	✓	✓	✓	✓	....	....	....	Cartridge Brass.........	
....	Fair	840	....	......	..	..	..	✓	✓	✓	✓	....	....	....	Rod Brass...............	
....	Slightly better than copper	870	....	......	..	..	..	✓	✓	✓	✓	....	....	....	Red Brass...............	
....	Tough	870	....	......	✓	✓	✓	✓	✓	✓	✓	....	....	....	Commercial Bronze......	
....	Tough	....	....	......	..	✓	✓	✓	✓	✓	✓	....	....	....	Phosphor Bronze.......	
....	Tough	760 to 900	Works readily	......	✓	✓	✓	✓	✓	✓	✓	....	....	Used when copper is to be in contact with reducing gases at elevated temperatures	Deoxidized Copper......	
....	Good	....	....	......	..	..	..	✓	✓	✓	✓	....	....	....	Hardware Bronze.......	
....	Fair	....	....	......	✓	✓	✓	✓	✓	✓	✓	....	....	....	18-per-cent Nickel Alloy..	

PLATE XIV.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PART V*b*

Corrosion-Resistant Properties

- American Brass Co.
- American Metal Products Co.
- Barber Asphalt Co.
- Chase Brass & Copper Co.

R = Recommended. N = Not recommended. V = Varies with individual conditions; consult manufacturer.

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																					
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydrocarbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen		Chlorine	
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature,
American Brass Co.	Admiralty	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Tobin Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Grade "C" Phosphor Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Grade "D" Phosphor Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Grade "A" Phosphor Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Commercial Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Red Brass, 85 per cent	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Red Brass, 80 per cent	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Deep Drawing Brass 70/30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Common High Brass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Hard Ware Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Ambrac "A"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Ambrac "B"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	18-per-cent Nickel Alloy (Grade "A")	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Tempaloy "A"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Tempaloy "B"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Everdur	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Aluminum Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Deoxidized Copper	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
American Metal Products Co.	Ampco	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Barber Asphalt Co.	Barberite	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Chase Brass & Copper Co.	Admiralty	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Chamet Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Common High Brass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Cartridge Brass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Red Brass	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Commercial Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Deoxidized Copper	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Hardware Bronze	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	18-per-cent Nickel Alloy	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

[a] Above room temperature.

PART V*b*. CORROSION-RESISTANT PROPER

Chlorine		Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia		Fused Caustic Alkalis		Fused Chlorides			Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				
deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Form of Material	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent
....	....	....	....	....	....	....	....	....	....	....	20	RV	N	N	20	N	N	N	20	N	N	N	20	RV	RV	..	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20
											c	RV	N	N	c	N	N	N	c	N	N	N	c	RV	..	..	c	RV	RV	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	N	N	N	20	N	N	N	20	N	N	N	20	RV	N	N	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20
											c	N	N	N	c	N	N	N	c	N	N	N	c	RV	N	N	c	RV	RV	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	V	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	V	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	R	R	R	20
											c	RV	RV	NV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	N	c	N	N	N	c	R	R	R	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	N	N	20	N	N	N	20	N	N	N	20	RV	N	N	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20
											c	RV	N	N	c	N	N	N	c	N	N	N	c	RV	N	N	c	RV	N	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	RV	N	N	20	N	N	N	20	RV	N	N	20
											c	N	N	N	c	N	N	N	c	N	N	N	c	N	N	N	c	RV	N	N	c	N	N	N	c	N	N	N	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	V	20	N	N	N	20	RV	N	N	20	RV	RV	V	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	V	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	RV	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	RV	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
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											c	RV	RV	NV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	N	N	N	c	RV	RV	RV	c	RV	RV	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	RV	20	N	N	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	RV	c	N	N	N	c	N	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	V	20	N	N	N	20	RV	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	V	c	N	N	N	c	RV	N	N	c	RV	RV	RV	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	R	R	R	20	N	N	N	20	V	V	V	20	R	R	R	20	R	R	R	20	V	V	V	20	R	R	R	20
....	....	....	....	....	....	....	....	....	....	Cast	20	R	R	N	20	N	N	N	20	N	N	N	20	N	N	N	...	..	..	..	20	N	N	N	20	V	V	V	...
											c	R	R	N	c	N	N	N	c	N	N	N	c	N	N	N	...	..	..	..	c	N	N	N	c	V	V	V	...
....	....	....	....	....	....	....	....	....	....	....	20	R	R	V	20	RV	N	N	20	RV	N	N	20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20
											c	RV	RV	N	c	RV	N	N	c	RV	N	N	c	R	R	R	c	R	R	N	c	N	N	N	c	R	R	R	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	N	N	20	N	N	N	20	N	N	N	20	R	RV	RV	20	R	RV	N	20	N	N	N	20	R	RV	RV	20
											c	N	N	N	c	N	N	N	c	N	N	N	c	V	N	N	c	V	V	N	c	N	N	N	c	V	V	V	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	V	N	20	V	N	N	20	V	N	N	20	R	RV	RV	20	R	R	N	20	N	N	N	20	R	R	RV	20
											c	V	N	N	c	V	N	N	c	N	N	N	c	V	N	N	c	V	V	N	c	N	N	N	c	V	V	V	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	V	N	20	V	N	N	20	V	N	N	20	R	RV	RV	20	R	R	N	20	N	N	N	20	R	R	RV	20
											c	V	N	N	c	V	N	N	c	N	N	N	c	V	N	N	c	V	V	N	c	N	N	N	c	V	V	V	c
....	....	....	....	....	....	....	....	....	....	....	20	R	R	V	20	RV	N	N	20	RV	N	N	20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20
											c	RV	RV	N	c	RV	N	N	c	RV	N	N	c	R	R	R	c	R	R	N	c	N	N	N	c	R	R	R	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	V	20	RV	N	N	20	V	N	N	20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	RV	20
											c	RV	RV	V	c	N	N	N	c	V	N	N	c	R	R	R	c	R	R	N	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	RV	RV	V	20	RV	N	N	20	V	N	N	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	RV	20
											c	RV	RV	V	c	N	N	N	c	V	N	N	c	R	R	R	c	R	R	R	c	N	N	N	c	RV	RV	RV	c
....	....	....	....	....	....	....	....	....	....	....	20	R	R	V	20	RV	N	N	20	V	N	N	20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20
											c	RV	RV	N	c	RV	N	N	c	V	N	N	c	R	R	R	c	R	R	N	c	N	N	N	c	R	R	R	c
....	....	....	....	....	....	....	....	....	....	....	20	R	RV	V	20	V	N	N	20	V	N	N	20	R	R	R	20	R	RV	RV	20	N	N	N	20	RV	RV	RV	20
											c	RV	RV	N	c	N	N	N	c	V	N	N	c	R	R	R	c	RV	RV	RV	c	N	N	N	c	RV	RV	RV	c

PART V*b*. CORROSION-RESISTANT PROPERTIES.

												Corrosion in Media at Moderate Temperatures																			
Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
20	RV	RV	..	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	...	....	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	..	..	"	RV	RV	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	N	N	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	N	20	RV	20	V	20	RV	20	RV	20	RV
"	RV	N	N	"	RV	RV	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	N	"	RV	"	N	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	...	....	20	RV	20	N	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	N	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	R	R	R	20	R	RV	RV	20	RV	20	RV	20	RV	20	RV	20	V	20	RV
"	RV	RV	RV	"	RV	RV	N	"	N	N	N	"	R	R	R	"	R	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	N	N	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	N	N	"	RV	N	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	N	N	N	20	RV	N	N	20	N	N	N	20	RV	N	N	20	N	N	N	20	N	20	RV	20	N	20	N	20	RV	20	RV
"	N	N	N	"	RV	N	N	"	N	N	N	"	N	N	N	"	N	N	N	"	N	"	RV	"	N	"	N	"	RV	"	RV
20	RV	RV	V	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	...	....	20	RV	...	....	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	...	....	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	RV	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	RV	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	...	....	20	RV	20	N	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	N	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	N	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	RV	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	20	RV	20	RV	20	RV	20	RV	20	RV	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	RV	"	RV	"	RV	"	RV	"	RV	"	RV
20	RV	RV	RV	20	RV	RV	RV	20	N	N	N	20	RV	RV	RV	20	RV	RV	RV	...	....	20	RV	20	N	20	RV	20	V	20	RV
"	RV	RV	RV	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	...	....	"	RV	"	N	"	RV	"	V	"	RV
20	R	R	R	20	R	R	R	20	V	V	V	20	R	R	R	20	R	R	R	20	R	20	V	20	R	20	V	20	R	20	V
20	N	N	N	...	..	..	..	20	N	N	N	20	V	V	V	...	..	..	..	20	N	20	N	20	N	20	V	20	V	...	....
"	N	N	N	...	..	..	..	"	N	N	N	"	V	V	V	...	..	..	..	"	N	"	N	"	N	"	V	"	V	...	....
20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20	R	R	V	20	V	20	RV	20	V	20	V	20	RV	20	RV
"	R	R	R	"	R	R	N	"	N	N	N	"	R	R	R	"	R	R	RV	"	V	"	RV	"	V	"	V	"	RV	"	RV
20	R	RV	RV	20	R	RV	N	20	N	N	N	20	R	RV	RV	20	R	RV	RV	20	N	20	RV	20	V	20	V	20	RV	20	RV
"	V	N	N	"	V	V	N	"	N	N	N	"	V	V	V	"	RV	RV	RV	"	N	"	RV	"	V	"	V	"	RV	"	RV
20	R	RV	RV	20	R	R	N	20	N	N	N	20	R	R	RV	20	R	R	RV	20	N	20	RV	20	V	20	V	20	RV	20	RV
"	V	N	N	"	V	V	N	"	N	N	N	"	V	V	V	"	V	V	V	"	N	"	RV	"	V	"	V	"	RV	"	RV
20	R	RV	RV	20	R	R	N	20	N	N	N	20	R	R	RV	20	R	R	RV	20	N	20	RV	20	V	20	V	20	RV	20	RV
"	V	N	N	"	V	V	N	"	N	N	N	"	V	V	V	"	V	V	V	"	N	"	RV	"	V	"	V	"	RV	"	RV
20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20	R	R	RV	20	V	20	RV	20	V	20	V	20	RV	20	RV
"	R	R	R	"	R	R	N	"	N	N	N	"	R	R	R	"	R	R	RV	"	V	"	RV	"	V	"	V	"	RV	"	RV
20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	RV	20	R	R	RV	20	V	20	RV	20	V	20	V	20	RV	20	RV
"	R	R	R	"	R	R	N	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	V	"	RV	"	V	"	V	"	RV	"	RV
20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	RV	20	R	R	RV	20	N	20	R	20	V	20	V	20	V	20	RV
"	R	R	R	"	R	R	R	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	N	"	R	"	V	"	V	"	V	"	RV
20	R	R	R	20	R	R	RV	20	N	N	N	20	R	R	R	20	R	R	RV	20	V	20	RV	20	V	20	V	20	RV	20	RV
"	R	R	R	"	R	R	N	"	N	N	N	"	R	R	R	"	R	R	RV	"	V	"	RV	"	V	"	V	"	RV	"	RV
20	R	R	R	20	R	RV	RV	20	N	N	N	20	RV	RV	RV	20	R	RV	RV	20	V	20	RV	20	V	20	V	20	RV	20	RV
"	R	R	R	"	RV	RV	RV	"	N	N	N	"	RV	RV	RV	"	RV	RV	RV	"	V	"	RV	"	V	"	V	"	RV	"	RV

Plate XIV.

Data on Corrosion-Resistant and Heat-Resistant Alloys.

Part V*b*.

it and etable ices	Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Temperature		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Medium			
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Admiralty	American Brass Co.
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Tobin Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Grade "C" Phosphor Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Grade "D" Phosphor Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Grade "A" Phosphor Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Commercial Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Red Brass, 85 per cent	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Red Brass, 80 per cent	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Deep Drawing Brass 70/30	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Common High Brass	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Hard Ware Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Ambrac "A"	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Ambrac "B"	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	18-per-cent Nickel Alloy (Grade "A")	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Tempaloy "A"	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Tempaloy "B"	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Everdur	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Aluminum Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Deoxidized Copper	
V	20	R	20	V	20	R	20	R	20	R	...	....	....	....	Ampco	American Metal Products Co.
....	... ...	....	... ...	....	... ...	....	... ...	....	20 e	N N	...	....	....	Cast	Barberite	Barber Asphalt Co
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Admiralty	Chase Brass & Copper Co.
RV RV	20 e	V V	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Chamet Bronze	
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Common High Brass	
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Cartridge Brass	
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Red Brass	
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Commercial Bronze	
RV RV	20 e	RV RV	20 e	N N	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Deoxidized Copper	
RV RV	20 e	RV RV	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	Hardware Bronze	
RV RV	20 e	RV V	20 e	V V	20 e	R R	20 e	R R	20 e	RV RV	...	....	....	....	18-per-cent Nickel Alloy	

PLATE XV.
PROC. AM. SOC. TESTING MATS.
VOL. 30, PART I.

DATA ON CORROSION-RESISTANT AND
HEAT-RESISTANT ALLOYS.

PART VI*a*

Compositions and Physical and Mechanical Properties

Frontier Bronze Co.
Riverside Metal Co.
Scovill Manufacturing Co.
National Lead Co.
Fansteel Products Co.
American Rolling Mill Co.
Manganese Steel Forge Co.
Meehanite Metal Corp.

PART VI*b*

Corrosion-Resistant Properties

Riverside Metal Co.
Scovill Manufacturing Co.
National Lead Co.
Fansteel Products Co.
Manganese Steel Forge Co.

Manufacturer	Trade Name of Alloy	Nominal Chemical Composition, per cent	Forms of Material Manufactured								Types of Service for Which Recommended					Specific Gravity	Melting Range (Liquidus and Solidus Temperatures), deg. Cent.	Coefficient of Expans per deg.
			Castings	Forgings	Hot Rolled Bars	Cold Rolled or Drawn Bars	Plates and Sheets	Shapes	Tubes	Wire	Corrosion Resistance	High Temperature Service	Abrasion Resistance	Electrical	Typical Applications			Mean 0 to 100° C.
Frontier Bronze Co.	Titanium Aluminum Bronze No. 1	Cu 90.0, Al 10.0	✓	✓	...	...	...	...	...	...	✓	✓	✓	...	Gears	7.5	....	....
	Titanium Aluminum Bronze No. 5	Cu 89.0, Al 10.0, Fe 1.0	✓	✓	...	...	...	...	...	..	✓	✓	✓	...	Gears	7.5	....	....
Riverside Metal Co.	Omega Brand Nickel Silver, 18 per cent "A"	Cu 65.0, Ni 18.0, Zn 17.0	..	...	...	✓	✓	...	...	✓	✓	...	✓	✓	Plated silverware, cutlery, hardware, restaurant and store fixtures, food dispensers, auto and boat trimmings, etc.	8.75	....	.... ..
	Omega Brand Nickel Silver, 18 per cent "B"	Cu 55.0, Ni 18.0, Zn 27.0	..	...	...	✓	✓	...	...	✓	✓	...	✓	✓	Springs for electrical, radio and telephone equipment; resistance wire	8.50	....	0.0000183
	Omega Brand Phosphor Bronze Alloy No. 30	Cu 95.5, Sn 4.3, P 0.2	...	...	...	✓	✓	...	...	✓	✓	...	✓	✓	Springs and contacts in radio and electrical equipment, screen plates for paper manufacturing, bridge and construction plates	8.60	....	0.0000189
	Omega Brand Phosphor Bronze Alloy No. 47	Cu 91.6, Sn 8.25, P 0.15	...	...	..	✓	✓	...	...	✓	✓	...	✓	✓	Used where forming and endurance requirements are severe	8.55	....	....
	Omega Brand Phosphor Bronze Alloy No. 209	Cu 90.0, Sn 10.0, P trace	...	...	...	✓	✓	...	...	...	✓	...	✓	✓	Used in sulfide solutions in paper mill machinery	8.88	....	....
Scovill Manufacturing Co.	Adnic	Cu 70.0, Ni 29.0, Sn 1.0	✓	✓	✓	✓	✓	...	...	✓	✓	✓	...	...	....	8.92	1205[e]	....
	Spring Oreide	Cu 92.0, Sn 8.0	...	...	..	...	✓	...	...	..	✓	...	...	✓	Spring contacts	8.80	1030 to 825	....
National Lead Co.	Antimonial Lead (hard lead)	Pb 94.0, Sb 6.0	✓	...	...	...	✓	...	✓	✓	✓	...	...	✓	Tank linings, valves, pipes, pumps, roofing material, chemical equipment, anodes, electrolytic tanks, storage batteries	11.0	247 to 290	0.000027
	Chemical Lead	Pb 99.93, Cu 0.06	✓	...	..	...	✓	...	✓	✓	✓	...	...	✓	Tank linings, valves, pipes, pumps, roofing material, chemical equipment, anodes, electrolytic tanks, storage batteries, fuses	11.36	325 to 327	0.000029
Fansteel Products Co.	Tantalum	99.5 Pure	...	...	...	✓	✓	...	...	✓	✓	...	...	✓	Rectifiers, rayon spinnerets, chemically inert vessel linings	16.6	2850	0.0000065
American Rolling Mill Co	Armco Ingot Iron	C 0.012, Mn 0.018, P 0.004, S 0.023, Si 0.003	✓	✓	✓	✓	✓	✓	✓	✓	✓	...	...	✓	Culverts, roofing, siding, general galvanized iron work, welding wire	7.86	1530	....
Manganese Steel Forge Co.	Rol-Man	C 1.2, Mn 12.5, Si 0.15,	...	✓	✓	...	✓	...	...	✓	...	...	✓	✓	Screens, wear plates	7.85	....	....
Meehanite Metal Corp.	Meehanite	C 2 55, Mn 0.85, Si 1.30, S 0.10, P 0.15	✓	...	...	...	...	...	...	...	✓	...	✓	...	Dies, piston rings, cylinders, oil refinery equipment, railroad equipment	7.49	1380 to 1360	....

[b] Maximum. [c] Approximate. [e] Liquidus. [f] 10 000 000 Reversals. [u] Farmer rotating beam. [v] Elongation in

R=Recommended. N=Not recommended. V=Varies with individual conditions; consult manufacturer.

Manufacturer	Trade Name of Alloy	Corrosion in Hot Gaseous or Other Media																									
		Air		Oxidizing Fuel Gases		Reducing Fuel Gases		Carbon Monoxide		Carbon Dioxide		Hydrocarbons		Hydrogen Sulfide		Sulfur Dioxide		Sulfur Trioxide		Oxides of Nitrogen		Chlorine		Hydrochloric Acid Gas		Hydrogen, Nitrogen and Ammonia	
		Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.
Riverside Metal Co.	Omega Brand Nickel Silver 18 per cent "A"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Omega Brand Nickel Silver 18 per cent "B"	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Omega Brand Phosphor Bronze Alloy No 30	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Omega Brand Phosphor Bronze Alloy No. 47	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Omega Brand Phosphor Bronze Alloy No. 209	....	....	....	....	....	....	....	....	....	....	...	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
Scovill Manufacturing Co.	Adnic	500	25 000	....	....	....	....	500	25 000	500	25 000	500	25 000	....	....	....	....	....	....	....	....	....	....	....	....	....	....
	Spring Oreide	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....
National Lead Co.	Antimonial Lead (hard lead)	205	....	....	....	205	....	205	....	205	....	205	....	205	....	205	....	205	....	....	....	205	....	....	....	205	....
	Chemical Lead	315	....	315	....	315	....	315	....	315	....	315	....	315	....	315	....	315	....	....	....	315	....	....	....	315	....
Fansteel Products Co.	Tantalum	300	....	300	....	300	....	300	....	300	....	300	....	300	....	300	....	300	....	....	....	300	....	....	....	300	....
Manganese Steel Forge Co.	Rol-Man	205	....	205	....	205	....	205	....	205	...	205	....	205	....	205	....	205	....	205	....	205	....	205	....	205	....

[a] Above room temperature.

PART VI*a*. COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERT

Physical Properties								Mechanical Properties at Room Temperature																
ficient of Thermal Expansion, per deg. Cent.		Thermal Conductivity, C.G.S. Unit		Specific Heat		Specific Electrical Resistance, microhms per cu. cm.		Form for Which Data is Recorded	Tensile Strength, lb. per sq. in.	Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Hardness Number			Impact Strength		Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit
C.	Other Ranges	Room Temperature	Other Temperature	Room Temperature	Other Temperature	Room Temperature	Other Temperature								Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.					
..	....	....	....	....	......	....	....	....	65 000 to 80 000	22 000 to 26 000	......	25.0 to 15.0	24.0 to 16.0	......	90 to 100	....	....	....	....	....	19 000	....	....	...
..	....	....	....	....	......	....	....	....	65 000 to 80 000	23 000 to 28 000	......	30.0 to 15.0	29.0 to 21.0	......	92 to 100	....	....	....	....	....	19 000	....	....	...
..	....	....	....	....	......	28.3	....	Plates and sheets	55 000 to 90 000	......	......	40.0 to 1.0	....	......	....	....	....	....	....	....	......	....	....	...
								Wire	55 000 to 140 000	......	......	55.0	....	....	....	....	....	....	....	....	......	....	....	...
183	....	....	....	....	......	31.4	....	Plates and sheets	60 000 to 125 000	......	......	40.0 to 1.0	....	20 000 000	....	....	....	....	....	....	......	....	....	...
								Wire	60 000 to 160 000	......	......	50.0 to 1.0	....	20 000 000	....	....	....	....	....	....	......	....	....	...
189	....	....	....	....	......	11.6	....	Cold rolled bars	50 000 to 100 000	......	......	35.0 to 5.0	....	16 000 000	....	....	....	....	....	....	......	....	....	...
								Plates and sheets	45 000 to 115 000	......	......	40.0 to 0.5	....	16 000 000	....	....	....	....	....	....	......	....	....	...
								Wire	45 000 to 160 000	......	......	60.0 to 0.5	....	16 000 000	....	....	....	....	....	....	......	....	....	...
..	....	....	....	....	......	14.8	....	Cold rolled bars	60 000 to 110 000	......	......	45.8 to 8.0	....	14 500 000	....	....	....	....	....	....	......	....	....	...
								Plates and sheets	51 000 to 130 000	......	......	50.0 to 1.0	....	14 500 000	....	....	....	....	....	....	......	....	....	...
..	....	....	....	....	......	16.1	....	Plates and sheets	135 000[b]	......	......	70.0 to 1.0	....	......	....	....	....	....	....	....	......	....	....	...
..	....	0.094	....	....	......	42.7	....	Hot rolled bars	64 000	35 600	30 500	46.0	72.0	......	....	....	....	....	....	....	......	....	....	...
								Cold rolled bars	113 000	107 000	85 000	10.0	56.5	21 300 000	....	....	31.0	....	....	....	......	....	....	...
								Plates and sheets	94 000	93 600	......	16.0	....	......	....	"B" 95.0	38.0	....	....	....	......	....	....	...
								Wire	131 000	......	......	2.0	....	......	....	....	....	....	....	....	......	....	....	...
.	(25 to 300° C.) 0.0000182	0.079	....	....	......	13.2	....	Plates and sheets	55 000 to 120 000	25 000 to 117 000	......	75.0 to 1.0	....	......	....	"B" 10.0 to 97.0	13 to 47	....	....	....	......	....	....	...
7	....	....	....	....	(0 to 100° C.) 0.0321	24.5	....	Castings	6 000	3 000	......	6.0	90.0	......	11.8	....	....	....	....	....	......	....	....	...
								Rolled or extruded	3 000	1 600	......	75.0	....	......	9.0	....	....	....	....	....	......	....	....	...
9	....	....	....	....	(0° C.) 0.0302 (100° C.) 0.0316 (300° C.) 0.0338 (327.4° C.) 0.0358	22.1	(78° C.) 14.1 (0° C.) 20.4 (90.4°C.) 28.0 (318° C.) 94.0 (600° C.) 100.2	Castings	1 750	1 000	800	40.0	90.0	2 000 000	5.5	....	....	1.5	....	....	......	1 340	....	...
								Extruded	1 750	......	......	60.0	95.0	......	....	....	....	....	....	....	......	....	....	...
								Rolled	1 750	......	......	60.0	95.0	......	....	....	....	....	....	....	......	....	....	...
65	....	0.130	....	....	(0° C.) 0.0365	15.5	....	Cold rolled bars	130 000	......	......	....	....	27 000 000	45.9	....	10.0	....	....	....	......	....	....	...
.	(20 to 300° C.) 0 0000129 (20 to 900° C.) 0.0000147	0.16	0.116	....	......	10.0	....	Forgings	44 000	27 000	......	41.2	75.6	29 270 000	....	....	....	....	....	....	......	....	....	...
								Hot rolled bars	43 400	30 000	......	33.5[v]	74.0	29 270 000	90	"B" 46.1	....	....	....	....	20 600	19 200	....	...
								Cold rolled bars	62 000	58 500	......	9.2[v]	68.2	29 270 000	137	"B" 79.7	....	....	....	....	......	....	....	...
								Plates and sheets	44 000 to 42 100	27 500 to 29 300	......	25.0	....	......	....	"B" 39.7	....	....	....	....	......	....	....	...
.	....	....	....	....	......	....	....	Forgings	140 000 to 155 000	......	......	50.0 to 35.0	....	......	....	....	....	....	....	80 000 to 85 000	65 000 to 75 000	....	....	...
								Hot rolled bars	140 000[c]	......	......	45 0 to 35 0	....	......	190	....	....	....	....	80 000 to 85 000	60 000	....	....	...
								Cold rolled bars	190 000	......	......	20.0[v]	....	......	....	....	....	....	....	....	......	....	....	...
								Plates and sheets	140 000	......	......	45.0 to 35.0	....	......	190	....	....	....	....	70 000 to 80 000	60 000	....	....	...
								Wire	193 000	......	......	20.0[v]	....	......	....	....	....	....	....	....	130 000 to 137 000	....	....	...
.	....	....	....	....	......		....	Castings	50 500	......	......	0.4	0.0	22 000 000	290	....	45.0	6.9	....	....	......	....	55 000	...

ation in 8 in.

PART VI*b*. CORROSION-RESISTANT PROPERTIES.

en, and ia	Fused Caustic Alkails		Fused Chlorides		Form of Material	Sulfuric Acid				Nitric Acid				Hydrochloric Acid				Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid	
Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.	Maximum Temperature, deg. Cent., for Continuous Operation	Working Stress at Maximum Temperature, lb. per sq. in.		Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	
...	....	....	....	....	....	20	R	R	R	20	..	N	N	20	R	..	..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	.....
						70	R	R	..	...	..	..	..	...	..	..	..	...	..	..	..	70	R	R	R														
...	....	....	....	....	....	20	R	R	R	20	..	N	N	20	R	..	..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	.....
						70	R	R	..	...	..	..	..	...	..	..	..	...	..	..	..	70	R	R	R														
...	....	....	....	....	....	20	R	R	R	20	N	N	N	...	..	..	..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	.....
						70	R	..	..	...	..	..	..	...	..	..	..	...	..	..	..	70	R	R	R														
...	....	....	....	....	....	20	R	R	R	20	N	N	N	...	..	..	..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	.....
						[c]	R	R	..	...	..	..	..	...	..	..	..	...	..	..	..	[c]	R	R	R														
...	....	....	....	....	....	20	R	R	R	20	N	N	N	...	..	..	..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	.....
						70	R	R	..	...	..	..	..	...	..	..	..	...	..	..	..	70	R	R	R														
...	....	....	....	....	....	20	R	N	N	20	N	N	N	20	R	N	N	20	R	R	N	20	R	R	N	20	N	N	N	20	R	R	R	20	R	R	..	...	.....
...	....	....	....	....	....	20	..	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	R	R	R	20	R	N	N	20	N
...	....	....	....	....	....	20	R	R	R	20	V	N	V	20	R	R	R	20	V	V	V	20	R	R	V	20	R	R	R	20	R	R	R	20	V	V	V	20	V
						100	R	R	R	100	N	N	N	100	R	R	V	100	V	V	V	100	R	R	V	100	R	R	R	100	R	R	R	100	V	V	V	[c]	V
						Boiling	V	V	N	Boiling	N	N	N	Boiling	R	V	V	Boiling	V	V	V	Boiling	N	N	N	Boiling	R	R	R	Boiling	V	V	V	Boiling	V	V	V		
...	....	....	....	....	....	20	R	R	R	20	V	N	R	20	V	V	N	20	V	V	V	20	V	V	V	20	R	R	R	20	R	R	R	20	V	V	V	20	R
						100	R	R	R	100	V	N	N	100	V	V	N	100	V	V	V	100	V	V	V	100	R	R	R	100	R	R	R	100	V	V	V	[c]	V
						Boiling	V	V	N	Boiling	N	N	N	Boiling	V	N	N	Boiling	V	V	V	Boiling	V	N	N	Boiling	R	R	R	Boiling	R	R	R	Boiling	V	V	V		
...	....	....	300	....	All forms	20	R	R	R	20	R	R	R	20	R	R	R	20	R	R	R	20	V	V	N	20	R	R	R	20	R	R	R	20	R	R	R	20	N
						[c]	R	R	R	[c]	R	R	R	[c]	R	R	R	[c]	R	R	R	[c]	N	N	N	[c]	R	R	R	[c]	R	R	R	[c]	R	R	R	[c]	N
...	205	....	205	...	...	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N

COMPOSITIONS AND PHYSICAL AND MECHANICAL PROPERTIES.

Mechanical Properties at Room Temperature																		Mechanical Properties at Elevated Temperatures					
					Hardness Number			Impact Strength															
Yield Point, lb. per sq. in.	Proportional Limit, lb. per sq. in.	Elongation in 2 in., per cent	Reduction of Area, per cent	Elastic Modulus, lb. per sq. in.	Brinell	Rockwell "C" Scale	Scleroscope	Charpy, ft-lb.	Izod, ft-lb.	Compressive Strength, lb. per sq. in.	Compressive Yield Point, lb. per sq. in.	Compressive Proportional Limit, lb. per sq. in.	Maximum Shear Strength (Torsion), lb. per sq. in.	Shear Strength at Proportional Limit (Torsion), lb. per sq. in.	Angle of Twist at Rupture, deg. per in.	Modulus of Rigidity, lb. per sq. in.	Endurance Limit, lb. per sq. in.	Form for Which Data is Recorded	Temperature, deg. Cent.	Safe Working Stress, lb. per sq. in.	Mean Rate of Creep	Method of Stress Determination	Ma
22 000 to 26 000	......	25.0 to 15.0	24.0 to 16.0	......	90 to 100	....	....	....	....	....	19 000	....	....	......	....	......	....	....	....	....	....	....	......
23 000 to 28 000	......	30.0 to 15.0	29.0 to 21.0	......	92 to 100	....	....	....	....	....	19 000	....	....	......	....	......	....	....	....	....	....	....	......
......	......	40.0 to 1.0	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machine
......	......	55.0	....	....	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	40.0 to 1.0	....	20 000 000	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machine
......	......	50.0 to 1.0	....	20 000 000	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	35.0 to 5.0	....	16 000 000	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machine
......	......	40.0 to 0.5	....	16 000 000	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	60.0 to 0.5	....	16 000 000	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	45.8 to 8.0	....	14 500 000	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machines
......	......	50.0 to 1.0	....	14 500 000	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	70.0 to 1.0	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machines
35 600	30 500	46.0	72.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machines
107 000	85 000	10.0	56.5	21 300 000	....	....	31.0	....	....	....	......	....	....	......	....	......	....						
93 600	......	16.0	....	......	....	"B" 95.0	38.0	....	....	....	......	....	....	......	....	......	....						
......	......	2.0	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....						
25 000 to 117 000	......	75.0 to 1.0	....	......	....	"B" 10·0 to 97.0	13 to 47	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Machines
3 000	......	6.0	90.0	......	11.8	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Easily m
1 600	......	75.0	....	......	9.0	....	....	....	....	....	......	....	....	......	....	......	....						
1 000	800	40.0	90.0	2 000 000	5.5	....	....	1.5	....	....	......	1 340	....	......	....	782 000	360[t]	....	....	....	....	....	Easily ma
......	......	60.0	95.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	60.0	95.0	......	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	....	....	27 000 000	45.9	....	10.0	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Similar to copper
27 000	......	41.2	75.6	29 270 000	....	....	....	....	....	....	......	....	....	......	....	......	....	....	....	....	....	....	Comparal steel if "rake"
30 000	......	33.5[v]	74.0	29 270 000	90	"B" 46.1	....	....	....	....	20,600	19 200	....	......	....	......	26 000[u]						
58 500	......	9.2[v]	68.2	29 270 000	137	"B" 79.7	....	....	....	....	......	....	....	......	....	......	....						
27 500 to 29 300	......	25.0	....	......	....	"B" 39.7	....	....	....	....	......	....	....	......	....	......	....						
......	......	50.0 to 35.0	....	......	....	....	....	....	....	80 000 to 85 000	65 000 to 75 000	....	....	......	....	......	....	....	....	....	....	....	Practicall machin edged t
......	......	45 0 to 35 0	....	......	190	....	....	....	....	80 000 to 85 000	60 000	....	....	......	....	......	....						
......	......	20.0[v]	....	......	....	....	....	....	....	....	......	....	....	......	....	......	....						
......	......	45 0 to 35 0	....	......	190	....	....	....	....	70 000 to 80 000	60 000	....	....	......	....	......	....						
......	......	20.0[v]	....	......	....	....	....	....	....	....	130 000 to 137 000	....	....	......	....	......	....						
......	......	0.4	0.0	22 000 000	290	....	45.0	6.9	....	....	......	....	55 000	......	....	......	....	....	....	....	....	....	......

PART VI*b*. CORROSION-RESISTANT PROPERTIES.

																					Corrosion in Media at Moderate Temperatures											
	Acetic Acid				Sodium Hydroxide				Ammonium Hydroxide				Sea Water and Brines				Calcium and Magnesium Brines				Hydrofluoric Acid		Phosphoric Acid		Chlorine in Aqueous Solution		Mine Waters		Fatty Acids		Fruit and Vegetable Juices	
Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.	Very Dilute	Moderate Dilution	Concentrated	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.	
..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	20	R	20	R
..	...	..	..	..	70	R	R	R																								
..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	20	R	20	R
..	...	..	..	..	70	R	R	R																								
..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	20	R	...	....
..	...	..	..	..	70	R	R	R																								
..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	20	R	...	....
..	...	..	..	..	[c]	R	R	R																								
..	20	R	R	R	20	R	R	R	20	N	N	N	20	R	R	R	...	..	..	..	...	....	...	....	...	....	20	R	20	R	...	....
..	...	..	..	..	70	R	R	R																								
N	20	R	R	N	20	R	R	N	20	N	N	N	20	R	R	R	20	R	R	..	...	....	20	R	20	N	20	N	20	R	20	R
N	20	N	N	N	20	N	N	N	20	N	N	N	20	R	R	F	20	R	N	N	20	N	...	....	20	N	20	N	20	R	20	V
R	20	V	V	V	20	R	R	V	20	R	R	R	20	R	R	R	20	V	V	V	20	V	20	R	20	R	20	R	20	V	20	N
V	100	V	V	V	100	R	R	V	100	R	R	R	100	R	R	R	100	V	V	V	[c]	V	[c]	V	...	....	[c]	V	[c]	V	...	....
V	Boiling	V	V	V	Boiling	N	N	N	Boiling	R	R	R	Boiling	V	V	V	Boiling	V	V	V												
N	20	V	V	V	20	V	V	V	20	R	R	R	20	R	R	R	20	V	V	V	20	R	20	R	20	R	20	R	20	V	20	N
N	100	V	V	V	100	V	V	V	100	R	R	R	100	R	R	R	100	V	V	V	[c]	V	[c]	R	[c]		[c]	V	[c]	V	[c]	
N	Boiling	V	V	V	Boiling	V	N	N	Boiling	R	R	R	Boiling	R	R	R	Boiling	V	V	V												
R	20	R	R	R	20	V	V	N	20	R	R	R	20	R	R	R	20	R	R	R	20	N	20	R	20	R	20	R	20	R	20	R
I.	[c]	R	R	R	[c]	N	N	N	[c]	R	R	R	[c]	R	R	R	[c]	R	R	R	[c]	N	[c]	R	[c]	R	[c]	R	[c]	R	[c]	R
N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	N	N	20	N	20	N	20	N	20	N	20	N	20	N

PLATE XV.
DATA ON CORROSION-RESISTANT AND HEAT-RESISTANT ALLOYS.

PARTS VI*a* AND VI*b*.

Fabricating Properties														Trade Name of Alloy	Manufacturer
Machining	Hot Working		Cold Working	Welding					Brazing	Soldering	Precautions to be Observed				
	Optimum Temperature Range, deg Cent.	Descriptive Information	Approximate Average Cold Reduction Without Anneal, per cent	Forge	Metallic Arc	Carbon Arc	Oxy-Gas	Resistance			In Design	In Fabricating	In Use		
....	....	....	......	..	..	..	..	..	..	..	....	....	....	Titanium Aluminum Bronze No. 1	Frontier Bronze Co.
....	....	....	......	..	..	..	..	..	..	..	....	....	....	Titanium Aluminum Bronze No. 5	
Machines easily	....	....	50.0	..	✓	✓	✓	✓	✓	✓	....	....	....	Omega Brand Nickel Silver, 18 per cent "A"	Riverside Metal Co.
Machines easily	....	....	50.0	..	✓	✓	✓	✓	✓	✓	....	....	....	Omega Brand Nickel Silver, 18 per cent "B"	
Machines easily	....	....	50.0	..	✓	✓	✓	✓	✓	✓	....	....	....	Omega Brand Phosphor Bronze Alloy No. 30	
Machines easily	....	....	50.0	..	✓	✓	✓	✓	✓	✓	....	....	....	Omega Brand Phosphor Bronze Alloy No. 47	
Machines easily	....	....	50.0	..	✓	✓	✓	✓	✓	✓	....	....	....	Omega Brand Phosphor Bronze Alloy No. 209	
Machines easily	850 to 1100	....	60.0	..	✓	..	✓	✓	✓	✓	....	....	....	Adnic	Scovill Manufacturing Co.
Machines easily	....	....	50.0	..	✓	..	✓	✓	✓	✓	....	....	....	Spring Oreide	
Easily machineable	....	....	......	..	..	..	✓	..	✓	✓	....	....	....	Antimonial Lead (hard lead)	National Lead Co.
Easily machineable	....	....	Unlimited	..	..	..	✓	..	..	✓	....	....	Avoid mechanical injury to lead, which is easily dented or pierced	Chemical Lead	
Similar to tough copper	....	Hot worked in vacuo only	......	..	..	✓	..	✓	..	..	....	....	Do not heat in air over 300° C.	Tantalum	Fansteel Products Co.
Comparable to mild steel if given more "rake"	....	Work above 1050° C. or below 850° C.	......	✓	✓	✓	✓	✓	✓	✓	....	Do not hot work between 850 to 1050° C.	....	Armco Ingot Iron	American Rolling Mill Co.
Practically non-machineable with edged tool	....	....	......	..	✓	..	..	..	..	✓	....	....	....	Rol-Man	Manganese Steel Forge Co.
....	....	....	......	..	..	..	..	..	..	..	....	....	....	Meehanite	Meehanite Metal Corp.

it and getable uices	Dye Liquors		Cuprammonium Solutions		Sea Air		Moist Temperature		Moist Sulfurous Atmosphere		Any Other Important Media			Form of Material	Trade Name of Alloy	Manufacturer
	Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Temperature, deg. Cent.		Media			
R	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Omega Brand Nickel Silver 18 per cent "A"	Riverside Metal Co.
R	.	....	...	....	20	R	20	R	20	R	...	....	....	....	Omega Brand Nickel Silver 18 per cent "B"	
....	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Omega Brand Phosphor Bronze Alloy No. 30	
....	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Omega Brand Phosphor Bronze Alloy No. 47	
....	...	....	...	....	20	R	20	R	20	R	...	....	....	....	Omega Brand Phosphor Bronze Alloy No. 209	
R	...	....	20	N	20	R	20	R	20	R	...	....	....	....	Adnic	Scovill Manufacturing Co.
V	20	N	20	N	20	R	20	R	20	N	...	....	....	....	Spring Oreide	
N	20 c	V V	20 c	V V	20	R	20	R	20	R	...	....	....	....	Antimonial Lead (hard lead)	National Lead Co.
N	20 c	V V	20	V V	20	R	20	R	20	R	...	....	....	....	Chemical Lead	
R R	20 c	R R	20 c	R R	20 c	R R	20 c	R R	20 c	R R	...	....	....	All forms	Tantalum	Fansteel Products Co.
N	20	N	20	N	20	N	20	N	20	N	...	....	....	....	Rol-Man	Manganese Steel Forge Co.